APPENDIX H

GPS PROCEDURES

GLOBAL POSITIONING SYSTEM CALIBRATION

PROCEDURE NO: 223 REVISION NO: 1

Global Positioning System Calibration

1. SCOPE

1.1 Purpose

To provide a standard procedure for the daily verification of the survey grade Global Positioning System (GPS) and Electronic Distance Measurement (EDM) survey instrument accuracy.

The GPS must be of survey grade. It is capable of differential phase processing for real-time kinematic surveys. The base / rover receiver location must be local to the site and utilize an established local calibration file. The system must be able to achieve a repeatable relative positioning accuracy of 0.1 foot vertical and 0.2 foot horizontal.

The EDM is a laser surveying instrument for use when the GPS is limited by adverse terrain conditions. The EDM must be able to interface with the GPS for accurate exchange of calibration, stake-out and measurement data. The system must be able to achieve a repeatable relative positioning accuracy of 0.1 foot vertical and 0.2 foot horizontal.

1.2 Applicability

The survey grade GPS and EDM systems will be checked prior to daily use against a known benchmark. If the daily check reading is questionable, the procedure will be repeated to verify the faulty measurement. The unit will then be sent to an authorized service company for repair and re-calibration should the check prove the instrument to be faulty.

2. REFERENCES

2.1 Applicable Reference Manual for the EDM system (This is only applicable for the specific equipment discussed, alternate survey grade equipment would use the reference manual specific to that equipment.)

2.2 Applicable Reference Manual for the GPS system (This is only applicable for the specific equipment discussed, alternate survey grade equipment would use the reference manual specific to that equipment.)

3. DEFINITIONS

3.1 Electronic Data Measurement

Electronic Data Measurement or EDM is the technology of obtaining measurements with an optical instrument equipped with a laser transmitter objective and receiver lens.

3.2 Global Positioning System

The GPS is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. GPS uses these "man-made stars" as reference points to calculate positions accurate to a matter of meters. Advanced forms of GPS can make measurements to better than a centimeter.

4. REQUIREMENTS

4.1 Equipment, Materials and Tools

- GPS base / rover system capable of broadcasting / receiving differential phase corrections for real-time stake-out and kinematic surveying.
- EDM system capable of integrating with the GPS
- Associated software to import, export and review survey data

4.2 Precautions

Instruments should not be used during periods of rainfall or heavy snowfall.

4.3 Acceptance Criteria

The GPS and EDM measurement to a known benchmark should be within 0.2 feet horizontal and 0.1 feet vertical.

5. PROCEDURE

5.1 Factory Calibration

Each instrument will be repaired and factory calibrated when instrument readings are questionable (i.e., fail the daily check).

5.2 Field Validation

5.2.1 GPS

5.2.1.1 The field validation must be measured from a known benchmark and be within the defined accuracy limits. The operations of the GPS for field validation are specific to the make and model used.

5.2.2 EDM

5.2.2.1 The field validation must be measured from a known benchmark and be within the defined accuracy limits. The operations of the EDM for field verification are specific to the make and model used.

5.2.2.2 Note time of validation in field logbook for both the GPS and EDM systems.

6. RECORDS/REPORTS/NOTIFICATIONS

The following documents will be maintained as quality records:

- Database of recorded benchmark and control point measurements
- Maps of control point locations
- Document that daily calibration was performed in the field logbook.

GLOBAL POSITIONING SYSTEM OPERATION

PROCEDURE NO: 224 REVISION NO: 1

GLOBAL POSITIONING SYSTEM OPERATION

1. SCOPE

1.1 Purpose

To provide a standard procedure for the daily operation of the Global Positioning System (GPS) and the Electronic Distance Measurement (EDM) survey instrument.

The GPS must be of survey grade quality with the capability of differential phase processing for real-time kinematic surveys.

The EDM is a laser surveying instrument for use when the GPS is limited by adverse terrain conditions. The EDM must be able to interface with the GPS for accurate exchange of calibration, stake-out and measurement data.

1.2 Applicability

This procedure applies to GPS surveying activities.

2. REFERENCES

2.1 Procedure 223 Global Positioning System Calibration

2.2 Applicable reference manual for the GPS and EDM systems.

3. DEFINITIONS

3.1 Electronic Data Measurement

Electronic Data Measurement or EDM is the technology of obtaining measurements with an optical instrument equipped with a laser transmitter objective and receiver lens.

3.2 Global Positioning System

The Global Positioning System is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. GPS uses these "man-made stars" as reference points to calculate positions accurate to a matter of meters. Advanced forms of GPS can make measurements to better than a centimeter.

4. REQUIREMENTS

4.1 Equipment, Materials and Tools

- GPS base / rover system capable of broadcasting / receiving differential phase corrections for real-time stake-out and kinematic surveying.
- EDM system capable of integrating with the GPS
- Associated software to import, export and review survey data
- GPS / EDM equipment of same or better quality may be substituted
- Substitute equipment must meet the acceptance criteria

4.2 Precautions

Instruments should not be used during periods of rainfall or heavy snowfall.

4.3 Acceptance Criteria

The GPS and EDM measurement to a known benchmark should be within 0.1 feet horizontally and vertically.

5. PROCEDURE

5.1 GPS Calibration

Prior to operating the GPS, a local calibration needs to be established. This action consists of surveying local known benchmarks to establish a network in both local and WGS84 coordinates. By comparing both sets of data, a set of transformations is derived to allow the GPS to survey in local coordinates for Easting, Northing and elevation.

5.2 Surveying

5.2.1 GPS

Detailed procedures for a GPS survey will vary with the manufacture and model. The general parameter to follow is the Positional Dilution of Precision (PDOP). This is a measurement of the strength of satellite geometry and is related to the spacing and position of the satellites in the sky. A high PDOP number indicates that the satellites are in a poor configuration and the resultant GPS measurement can be in error. Acceptable survey grade GPS measurements must be within the PDOP range of six (6) or less.

5.2.2 EDM

Detailed procedures for an EDM survey will vary with the manufacture and model.

5.2.3 Data Transfer

Detailed procedures for data transfer will vary with the manufacture and model.

6. RECORDS/REPORTS/NOTIFICATIONS

The following documents will be maintained as quality records:

- Database of recorded benchmark and control point measurements
- Database of all surveyed topography, land monuments, excavation topography and verification points.
- Maps of control point locations

APPENDIX I

GOLDER ASSOCIATES TECHNICAL PROCEDURES

TP-1.1-14

Revision 1

RECORD OF REVISION

Section	Description
7.	Expanded list of equipment and materials
8.3 and Figure 1	Added seismic refraction data sheet
8.4	Added new section for explosives procedure and documentation
Figure 2	Added new Blasting Record form
8.6 & Figure 3	Changed Procedure Alteration Checklist to Field Change Request

1. PURPOSE

This technical procedure establishes uniform methodology for executing a shallow seismic refraction survey to map subsurface structures.

2. APPLICABILITY

This technical procedure is applicable to all seismic refraction surveys using Bison, or equivalent, instrumentation.

3. DEFINITIONS

3.1 P-waves. Compressional or sound waves that have the highest velocity of all the seismic waves.

3.2 First arrivals. The first wave to arrive at a geophone from a seismic source.

3.3 Geophone spread. The arrangement of geophones in relation to the position of the energy source.

4. REFERENCES

Haeni, F.P., 1988, Application of Seismic-Refraction Techniques to Hydrologic Studies: U.S. Geological Survey, Techniques of Water-Resources Investigations of the U.S.G.S., Book 2, Chapter D2, U.S. Government Printing Office, Washington, D.C.

Bison Instruments, Inc., 1990, Bison 7000 Series DIFP Seismograph Instruction Manual, Minneapolis, Minnesota.

5. DISCUSSION

Seismic refraction methods measure the time it takes for a P-wave generated by a sound source to travel down through the layers of the Earth and back up to detectors placed on the land surface. By measuring the traveltime of the sound wave and applying the laws of physics that govern the propagation of sound, the subsurface geology can be inferred. The field data, therefore, will consist of measured distances and seismic traveltimes. From this time-distance information, velocity variations and depths of individual layers can be calculated and modeled.

The seismic refraction method depends on the seismic velocity of the subsurface material increasing with depth. Geologic layers that have a seismic velocity slower than the layer above it can not be detected. Also, layers that do not have a significant velocity contrast from the surrounding layers or are relatively thin can not be detected.

The total depth of exploration for the seismic refraction method is limited by the power of the seismic source and the space available for the survey. The sources described in this procedure can detect layers to a depth of 100 feet in good conditions. Deeper exploration is possible with using more powerful explosives such as Kinestik.

6. RESPONSIBILITY

6.1 Field Geophysicists

All field geophysicists engaged in conducting seismic refraction surveys are responsible for compliance with this procedure.

7. EQUIPMENT AND MATERIALS

- Bison 7000 24 channel seismograph or equivalent
- 24 vertical geophones, 7 to 15 Hz
- Geophone cable with takeouts at 10 to 50 ft intervals
- Sledgehammer with plate
- Inertia trigger switches
- Trigger cable
- Blaster and appropriate cables (optional)
- Electric trigger shotgun shells (optional)
- Shovel (optional)
- Stakes, flagging, and compass
- Field logbook
- Bison 7000 operating manual
- Day boxes (optional)
- Kinestik blasting agents (optional)
- Detonators - Class C or 1.10 (optional)
- Seismic Data Sheets
- Blasting Record forms (optional)
- MSHA - approved ohmmeter (optional)

8. PROCEDURE

8.1 Establish the Survey Line

Establish an origin (Station 0) and reference the line from this origin to compass bearings. Previously established survey control coordinates should be used wherever possible. Otherwise, reference the origin to a significant landmark.

8.2 Equipment Set-up and Functional Tests

Perform equipment set up procedures and functional tests of the equipment, as outlined in the Bison 7000 operating manual. Lay out geophone lines and place geophones at 5 to 50-foot intervals along the survey line. Properly connect all geophones to the appropriate takeout and connect all geophone lines and trigger cables to the seismograph.

Perform a test shot using the sledgehammer as the seismic source. All shot locations should be in line with the geophones or only offset a short distance from this line. Print the results and verify that all channels are functioning and that the recording time and field geometry are correctly set on the seismograph.

8.3 Survey Procedure and Documentation

Record the following instrument parameters and field geometry in the field logbooks or on the seismic refraction data sheet (Figure 1):

- Geophone interval and location of Geophone #1;
- Shot number, location and distance to closest geophone;
- Shot direction: near (closest to the first geophone), middle (between the first and last geophones), far (closest to the last geophone);
- Seismic record length in milliseconds;
- Sample rate of the seismograph;
- Spread number;
- Record file name.

Using a sledgehammer or shotgun shells at the first shot location, record the shot and store the record in the digital memory of the seismograph. Print the record and verify that all first arrivals are visible. If the record is of poor quality more shots may be averaged into the record to enhance the signal to noise ratio or the shot may be completely redone.

When the first arrivals are clearly visible on the record then proceed to the next shot location and repeat the above steps. Normally, two forward, one middle and two reverse shots will be recorded into each geophone spread. The offset of the forward and reverse shots from the closest geophone depends on the objectives of the survey.

More than one geophone spread may be required in order to completely cover the length of the seismic line. When this occurs the spread number of each shot should be noted in the field logbook.

The relative elevation changes along the seismic line must be determined. This can be accomplished with a detailed topographic map or with direct measurements with a surveying system depending on the resolution requirements of the seismic survey.

All printouts, digital records and field logbooks shall be forwarded to the project files.

8.4 Explosives Procedure and Documentation (optional)

The field person in charge of the storage, transportation and use of 1.1D (Class C) or 1.4D (Class A) explosives shall have completed a MSHA approved blasting safety training course or equivalent, and shall have all necessary state, county, or city licenses or permits for the particular job location. This person shall be referred to as the "blaster" in this section.

The blaster shall insure that the handling, storage, transportation, and detonation of the explosives is done in accordance with federal, state, and local regulations. It is strongly recommended that only 1.1D (Class C) detonators and Kinestik blasting agents, or equivalent, be used. These products are much safer to use than 1.4D (Class A) explosives and, thus, have less stringent regulations.

The blaster shall record the following purchase information on the Blasting Record form (Figure 2):

- Description of detonators and blasting agents
- Name and location of supplier
- Date and quantity purchased
- Code date of detonators and blasting agents

The blaster shall also inventory the explosives every day and record the following information on the Blasting Record form:

- Location of detonations
- Design of shot (amounts and depths of burial)
- Date used
- Seismic line number and number of individual shots per line
- Number used and remaining of detonators and blasting agents
- Time of air blasts

The blaster shall sign the Blasting Record form and forward the original to the explosives records file with the office manager and a copy to the project file.

8.5 Data Reduction

All shot records will be downloaded from the seismograph to a computer for further processing and interpretation. The files may be transferred from the seismograph using the data transferring program MENU. Consult the Bison 7000 manual for specific details on data downloading.

The seismic refraction data may be processed using a variety of seismic refraction software packages such as SIP (Rimrock Geophysics, Golden, CO), SeisREFA (Oyo Corp., Houston, TX) or ViewSeis (ViewLog Ltd., Toronto, Canada). The basic processing procedure is as follows:

- Assign field geometry to each seismic record;
- Enter elevation changes along the seismic line;
- Pick the times of the first arrivals;
- Assign each arrival to a seismic layer;
- Determine seismic velocities of each layer from the data or other sources;
- Calculate and plot a depth model.

Variations in this procedure may occur especially if the Generalized Reciprocal Method (GRM) is used. Consult the appropriate software manuals and references for specific details on processing the seismic refraction data.

The results of the depth model may be displayed in a cross-section or plotted on a map depending on the requirements of the project.

8.6 Field Change Request

Variations from the established procedure requirements may be necessary due to unique circumstances encountered in the field. All variations from established procedures shall be documented on Field Change Request (Figure 3) and reviewed by the Project Manager and the QA Manager.

The Project Manager may authorize individual Field Geophysicists to initiate variations as necessary. If practical, the request for variations shall be reviewed by the Project Manager and the QA Manager prior to implementation. If prior review is not possible, the variation may be implemented immediately at the direction of the Field Geophysicist, provided that the Project Manager is notified of the variation within 24 hours of implementation, and the Field Change Request is forwarded to the Project Manager and QA Manager for review within 2 working days of implementation. If the variation is unacceptable to either reviewer, the activity shall be repeated or action shall be taken as indicated in the Comments section of the checklist.

All completed Field Change Requests shall be maintained in project records.

Golder Associates

'MIC REFRACTION SPREAD DATA SHEET

PROJECT NAME:		LINE & SPREAD #:	
JOB #:		DATE:	
FIELD CREW:			

LINE GEOMETRY

Geo.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Shot Loc.:																								
Spacings:																								
Locations:																								

SKETCH OF LINE LOCATION

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1		2		3		4		5		6		7		8		9		10		11		12	

Shot #/Near, Far, Mid/ Geo#	File #	Shot Loc.	Shot Offset X/Y	Source Type/ Stacks	Source depth	Sample rate/ # of samples	Delay (ms)	Filters (HC/LC)	Saved	Print	Time

FIGURE 1

SEISMIC REFRACTION SPREAD SHEET FORM

TP-1.1-14

'3 1024/SRSDS 1.1.14

Golder Associates

BLASTING RECORD
Golder Job Number:

Federal BATF License
9WA017206D12068

PURCHASE RECORDS (attach original documents)

Detonator Description	Company	Location	Date	Qty #	Code Date	Box
Blasting Agents Description	**Company**	**Location**	**Date**	**Qty #**	**Code Date**	**Box**

SHOT RECORDS

Location:
Shot Design:

Date	Seismic Line	# of shots	Cap Count		box	BA Count		box	Comments (Record time of air shots)
			used	remaining		used	remaining		

Page _____ of _____
Copy: Project File

Signature

Date

FIGURE 2
BLASTING RECORD FORM
TP-1.1-14

IP3 1024/BR1.1.14

FIELD CHANGE REQUEST

Golder Associates

Job/Task Number: ______________________________

Other Affected Documents: ______________________________

Requested Change: ______________________________

Reason for Change: ______________________________

Change Requested by: ______________________ Date ____________

Reviewed by: ______________________ Date ____________
GAI Project Manager

Comments: ______________________________

Reviewed by: ______________________ Date ____________
GAI QA Manager

Comments: ______________________________

FIGURE 3
FIELD CHANGE
REQUEST FORM
TP-1.1-14

Record of Revision
TP-1.2-2
Rev. 6

Section	Description of Revision
Throughout	Editorial and format change throughout
4.	Included new references
8.2.2.6	New paragraph detailing healed fractures
8.2.2.8	Included more explanation regarding Rock Quality Designation (RQD)
8.2.2.10	Included paragraph regarding Joint Condition Rating applicable to Bieniawski's RMR System and Barton's "Q" System
8.2.5 & 8.2.6	New Sections, Summary Geotechnical Logs for Mining Projects and Minimum Geotechnical Data Collection During Exploration Coring
8.6 & Figure 13	Changed Field Alteration Checklist to Field Change Request
Figures 1, 2, 3, & 11	Updated to reflect current practice
Figure 4	Changed to Rock Classification
Figure 12	New - Summary Geotechnical Log

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LIST OF FIGURES

1. PURPOSE

The purpose of this procedure is to establish a uniform and consistent method of geotechnical logging of rock core. The procedure also establishes standard methods to be followed in the handling and preparation of core for offsite shipment.

2. APPLICABILITY

This procedure applies to all Golder Associates Inc. personnel or (when invoked through procurement documentation) subcontractors assigned responsibilities for geotechnical logging of rock core.

3. DEFINITIONS

None.

4. REFERENCES

Golder Associates Inc. Technical Procedure TP-1.2-1, "Rock Core Drilling and Sampling"

Golder Associates Inc. Technical Procedure TP-1.2-4, "Oriented Coring"

GOLDLOG2 Program Documentation and User's Manual

Brown, E.T. (ed.), 1981, Rock Characterization Testing and Monitoring: ISRM Suggested Methods, Pergamon Press, for the International Society for Rock Mechanics.

Deere, D.U., 1968, Geological Considerations, Rock Mechanics in Engineering Practice, ed. R.G. Stagg and D.C. Zienkiewicz, Wiley, New York, pp. 1-20.

Deere, D.U., A.H. Merritt, and R.F. Coon, 1969, Engineering Classification of In-Situ Rock: Technical Report No. AFWL-TR-67-144, (prepared by the University of Illinois Department of Civil Engineering under U.S. Air Force Weapons Laboratory contract AF 29(601)-6850).

Deere, D.U., and D.W. Deere, 1989, Rock Quality Designation (RQD) After 20 Years. U.S. Army Corps of Engineers Contract Report GL-89-Y, Available from NTIS. AD/A207 597.

Hoek, E., and E.T. Brown, 1980, Underground Excavations in Rock. Published by the Institution of Mining and Metallurgy.

Goodman, R.F., 1980, Introduction to Rock Mechanics, J. Wiley and Sons.

Heuze, E.F., 1971, "Sources of Errors in Rock Mechanics Field Measurements, and Related Solutions", in the International Journal of Rock Mechanics and Mining Sciences, Vol. 8, pp. 297-310.

Travis, R.B., 1955, "Classification of Rocks", in Quarterly of the Colorado School of Mines, Volume 50, No. 1.

5. DISCUSSION

The purpose of this procedure is to document the standard method of geotechnical logging of rock core for Golder Associates Inc. projects in order to ensure consistent logging practices. Standard classifications suggested by the ISRM (Brown, 1981) or other recognized standards have been incorporated into the procedure where appropriate.

This procedure does not address other activities that are frequently conducted in combination with core logging, such as core drilling and selection of coring equipment; point load testing; installation of geotechnical or geohydrological instrumentation; field permeability testing; core orientation procedures; core sample shipment and testing; and logging procedures for soil borings. These items are addressed in separate procedures or project directives. However, a general familiarity with drilling procedures, geology, and rock engineering is assumed.

The Record of Drillhole format used for field logging and preparation of final drillhole logs has been developed to facilitate preparation of final logs using the GOLDLOG2 computerized rockcore logging system, which is documented separately (see References). Most commercial projects in the U.S. are still performed using English rather than metric units for measurements. While GOLDLOG2 can accommodate either measurement system, for simplicity and compatibility with current U.S. practices, this procedure will assume the English system is used. If GOLDLOG is not available, equivalent logs can be readily produced using a suitable template with a Macintosh or PC.

Core drilling is expensive and constitutes a major expenditure in an exploration or geotechnical investigation program. It is therefore essential to make every effort to obtain high quality core and to ensure that the maximum amount of data is obtained from the drill core, in addition to putting the resulting hole to maximum use such as by measuring water levels, permeability, and installing piezometers.

The quality of the core is a function of the equipment used and the skill of the driller in drilling and handling the core. Technical Procedure TP-1.2-1, "Rock Core Drilling and Sampling" provides details of core drilling equipment selection and drilling methods. A triple tube core barrel should be used on important projects where core is susceptible to damage or deterioration on handling. A double tube core barrel with a split inner tube is an acceptable alternative when the core is not susceptible to excessive deterioration on handling and is the minimum acceptable equipment that should be specified for geotechnical purposes. A double tube barrel with a solid inner tube is sometimes the only equipment available when geotechnical documentation is undertaken on core that is drilled primarily for mineral exploration purposes, but should only be used in competent, unbroken rock where the core can be transferred from the tube to a V-shaped core tray without damage. The core may be slid from the solid tube if it slides freely; otherwise the core should be pumped out of the tube using the mud pump. In any case, it must be transferred in such a way that fractures induced by handling will be minimized. It is not acceptable to beat the core out of the tube using a hammer or similar device. A face discharge diamond bit should be used to minimize erosion of the core in soft or friable ground.

The maximum amount of data will be collected from the drill core by using systematic documentation and testing methods as described in this procedure. It is recognized that no single procedure can be definitive or incorporate the most suitable logging methods for all field conditions. The purpose of developing this procedure is to present methods and standards which have been successfully applied for rock core logging under a wide variety of geotechnical conditions and which are compatible with the standard Golder Associates Inc. rock core logging form. This procedure should be directly applicable to (and should be strictly complied with for) the majority of rock core logging projects. Where it is necessary to modify the procedure, all modifications should be documented on the Field Change Request as noted in Section 8.6 below, and in the reports and notes that accompany the final logs.

Some cores are much easier to log than others. Sound, competent core with uniform lithology and few shears or fractures can be logged relatively easily and rapidly. Completely crushed or broken core can also often be described and logged relatively quickly. However, core with variable geological and structural conditions, or core which deteriorates due to stress relief cracking, desiccation or slaking can take much longer to log, particularly during the initial stages of a coring program when there has not been sufficient time to develop a familiarity with site conditions. When logging core, always keep in mind that the primary purpose of the core logs is to record information that conveys an accurate impression of the character of the rock cored. If the condition of the core changes with time, the character and rate of this change should be documented on the log.

6. RESPONSIBILITIES

6.1 Project Manager

The Project Manager is responsible for overall management of the core logging activities, but may delegate responsibilities to qualified geologists/field engineers. The Project Manager is responsible for approving all variations from the methods established by this procedure, for preparation of the overall scope of work for the core logging activity, for preparation of procurement documents for all subcontractors, and for briefing all field personnel on any requirements unique to the project.

6.2 Geologist/Field Engineer

The Geologist/Field Engineer is responsible for performing core logging in compliance with the requirements of this procedure, as well as for marking, handling, and packaging of core in preparation for shipment. The Geologist/Field Engineer is responsible for developing sufficient understanding of the ultimate goals of the investigation in order to properly record all required information and to be able to make sound decisions in the event of unforeseen situations.

7. EQUIPMENT AND MATERIALS CHECKLIST

- Record of Drillhole forms (See Figure 1)
- red, green, and black marking pens
- color control/grey scale charts
- core storage boxes
- styrofoam or wood core blocks
- rock hammer
- stove and pot
- paraffin
- plastic wrap
- aluminum foil
- history of hole forms
- heavy duty plastic bags (ziplock)
- hard hat
- steel-toed boots
- protractor
- engineer's scale
- ice chest (if sample freezing is possible)
- 35mm reflex camera, with tripod
- color print or slide film
- point load tester
- well sounder
- water bucket, brush, and spray bottle
- acid bottle (with 10% HCL solution)
- knife
- hand lens
- 16-25' carpenter's tape (marked in tenths of feet and inches)
- 50-300' reel-type tape (marked in tenths of feet and inches)

8. PROCEDURE

8.1 General Information

The Golder Associates Inc. Record of Drillhole form is the basic data recording sheet for rock core logging procedures. The Record of Drillhole form has been designed to facilitate collection of important geotechnical data during core logging, and presentation of the data using GOLDLOG2 for inclusion in reports. The final logs produced by GOLDLOG2 present data graphically where appropriate to maximize the visual impact of the logs. However, field data must always be recorded quantitatively, rather than by shading the graphic scales, in order to ensure accurate and complete data records and to minimize the risk of incorrect interpretations of field logs. The graphical representations show increasing black as the quality of the rock deteriorates (decreasing RQD, increasing fractures per foot, increasing degree of weathering, decreasing strength) so that fractured and weak zones are highlighted by large amounts of black in the graphic columns of the log. Quantitative data used to produce the graphic logs are always available from the original field logs on the GOLDLOG2 data files if these are required for further quantitative evaluation.

8.2 Completion of Record of Drillhole Forms

The field logging form is similar in format to the final logs produced by GOLDLOG2. An example of a Record of Drillhole form used for field logging is attached as Figure 1. A completed field Record of Drillhole form is included as Figure 2, and an example log plotted for inclusion in a report by GOLDLOG2 is included as Figure 3. The Record of Drillhole form is comprised of header, footer, and data sections.

8.2.1 Header and Footer Sections

The header and footer sections contain relevant information about the project and drillhole.

The following data should be specified on each Record of Drillhole form; please see the example form shown in Figure 2.

Header Section

Enter the drillhole number after the main title.

PROJECT:	Golder Associates Inc. project identifier, Owner/Project/State, e.g., CWMI/POND P-15/CA
PROJECT NO.:	Project and task number for drilling, e.g., 893-1114.007
LOCATION:	Project Location, e.g., KETTLEMAN HILLS FACILITY
DRILLING METHOD:	Type of drilling and bit size, e.g., NQ-3.
DRILLING DATE:	Start and completion dates of drilling, e.g., 3 JANUARY, 1989 - 5 JANUARY 1989
DRILL RIG:	Type and model of drilling, e.g., SKID MOUNTED LONGYEAR 44
DATUM:	Elevation datum - Mean Sea Level (MSL) or as specified.
COLLAR ELEVATION:	Surveyed elevation of collar relative to datum.
COORDINATES:	Surveyed northing and easting of collar.
AZIMUTH:	Surveyed azimuth of inclined drillhole at collar (use N/A - not applicable for vertical boreholes)
INCLINATION:	Surveyed inclination from horizontal of drillhole at collar or -90° for vertical down a drillhole.

Note: If collar elevation, coordinates, azimuth, and inclination are not surveyed, this must be noted and the method of estimating these should be specified on the log or in accompanying notes.

Footer Section

DEPTH SCALE:	Specify the depth scale in feet per inch (or meters per cm). 1"-1' is a typical scale for detailed logging of limited lengths of core; 1"=5' is typical for logging of longer drillholes.
DRILLING CONTRACTOR:	The name of the company undertaking the drilling.
DRILLER:	The name of the driller.
LOGGED:	The first initial and the last name of the field geologist or engineer who logged the core - do not use initials only.
CHECKED:	The first initial and last name of the individual who checked and approved the final logs.
DATE:	The date the final logs were approved.

8.2.2 Data Section

The data section in the standard Record of Drillhole form comprises fourteen columns in which to record pertinent information for geotechnical documentation. Although GOLDLOG2 plots some data graphically for visual presentation purposes, (e.g., RQD, fractures per foot, weathering, strength) quantitative data must always be recorded numerically on the field log. Scale lines used for graphical plots on the final logs are not included on the field logs; this is to facilitate numerical data recording. Always show changes in recorded data or classifications at their correct locations on the log; do not simply designate changes at core run limits for convenience.

8.2.2.1 Depth Scale

The Depth Scale is used to record the drillhole depth using the scale selected and recorded in the footer section. The scale selected will depend on the geological complexity of the core and the level of detail of logging. A scale of 1 inch = 1 foot, will result in 8 feet of core to a page; a scale of 1 inch = 5 feet will result in 40 feet of core to each page of the log.

8.2.2.2 Rock Type Description

The Description section allows for a complete and detailed lithologic description. Standard classification systems used for quantitative description and classification of rock are summarized in Figure 4, Rock Classification, which should be included as a figure in all reports that document rock core logging or rock classification. The rock description system used by Golder Associates is as follows:

"Weathered State, Structure, Color, Grain or Crystal size, Strength, ROCK TYPE." Since weathering and strength are generally documented continuously in individual columns, these are included in the rock description for completeness and to enable qualitative descriptions that are not incorporated into the continuous log, such as fresh inclusions within a moderately weathered matrix. Include the following items in the rock description system:

- Weathering - Classification according to ISRM standard (Section 8.2.2.11 and Figure 4) and qualitative description of any unusual weathering characteristics.

- Structure - Record any persistent structure in rock such as foliation, flow banding, bedding, lamination, grading, sorting, etc., and specify its dip with respect to the core axis. Describe bedding thickness according to the classification system in Figure 4.

- Color - Use color name from GSA Rock Color Chart of wet rock. If rock is composed of more than one color, list major colors starting with the most prominent.

- Grain or Crystal Size - Record the size of visible grains or crystals in millimeters or according to the Wentworth scale shown in Figure 4.

- Strength - Field estimate of intact strength based on ISRM classification (Section 8.2.2.12 and Figure 4), subsequently modified as necessary to reflect results of point load and/or unconfined compressive strength (UCS) tests. Provide qualitative description of factors that might affect strength such as weak layers and any seams for which strength tests are not representative.

- Rock Type - Colorado School of Mines Classification (Travis, 1955). Classification charts are included as Figures 5 through 7. It is important that rock type designations be correct. If in doubt regarding rock type use petrographic analyses. A petrographic microscope may be used to confirm rock type and provide more detailed information on mineral constituents and degree of alteration.

The formation or unit should also be identified within this column. Other items such as angularity should be included if they affect the mechanical characteristics of the rock and are not documented elsewhere on the log.

Vague, ambiguous, or undefined terms are neither necessary nor helpful and should not be used on the logs. All pertinent characteristics and properties should be recorded using standard classifications and descriptions. Terms such as large, small, thin, and thick are not suitable unless they are part of a quantitative classification system, and should be replaced by quantitative data obtained by measurement. Note that the terms "soft" and "hard" are not appropriate for describing rock strength; this is best described using the strength index and point-load test index. If hardness is an important parameter in the geotechnical documentation of the core, then it should be measured using a Schmidt hammer, Shore scleroscope, or other suitable instrument.

Field and final logs should be clear and concise and must not be open to possible misinterpretation. For this reason abbreviations and mnemonics should not be used except where they are defined on the log. The only exceptions are for length measurements (ft., in., m, cm, mm) and approx. for approximately. Use of the symbols ' and " for feet and inches is not acceptable.

8.2.2.3 Rock Type Graphic Log

The Graphic Log subsection of the Rock Type uses standard lithologic symbols available in GOLDLOG2 (or from Figures 8A and 8B if GOLDLOG2 is not being used to prepare the final logs) to represent the rock types encountered throughout the drillhole. Contacts between the rock types are represented as follows:

Contact Type	Representation on Graphic Log
Sharp	Solid horizontal line at contact location.
Gradation	Solid slanted line from start of gradational change to end of gradational change.
Inferred Contact	Dashed slanted line extending over length of inferred contact.
Erosional	Solid wavy line at contact location.
Fault	Heavy solid horizontal line at contact location.

8.2.2.4 Elevation/Depth

Record the depths at the beginning and end of each core run and the depth of lithologic boundaries to the nearest 0.1 foot. Use feet and decimals of a foot; do not use feet and inches. Elevation need not be calculated for field records since this is calculated by GOLDLOG2 based on the specified collar elevation, which may not be known during drilling.

8.2.2.5 Run Number

Record consecutive numbers for each core run, dividing runs by solid horizontal lines at the beginning and end of each run. Since core recovery and RQD are both calculated for each run, carry the horizontal lines across these columns.

8.2.2.6 Measuring Core Recovery, RQD, and Fractures Per Foot

Core Recovery, RQD, and fractures per foot should all be logged while the core is still in the tube liner or split tube, or immediately after it has been transferred to the core tray if a solid tube is used. If necessary, some other items such as detailed lithologic descriptions, logging of individual discontinuities, and strength testing, can be deferred until the core has been transferred to the core boxes. However, recovery, RQD, and fractures per foot should be logged while the core is in as close to its original condition as possible. If fracture logs can not be completed prior to boxing, all handling and boxing fractures should be clearly marked and discounted from the RQD and fracture logs.

Only natural fractures are counted for RQD and other fracture logs; drill-induced and handling fractures are excluded. It is sometimes difficult to distinguish natural fractures. As a guide, clean, fresh surfaces oriented at close to 90° to the core axis that can be rejoined with only a hair-line separation are typically drill-induced, while surfaces that are rounded, ground, weathered, contain infilling or coatings, often at some angle other than perpendicular to the core axis, or cannot be rejoined cleanly should be counted as natural fractures. If the origin of the fracture is uncertain, then it is counted in order to ensure values for the RQD and fracture logs that are conservative for most purposes. If the fracture data are used for applications such as predictions of rippability or blasting requirements, then this assumption will **not** be conservative.

Natural fractures may be open or filled, but old fractures that have been healed by quartz, calcite, or other cementing minerals are not counted if the core is intact across the healed discontinuity. The distinction between an open/filled fracture and a healed fracture is the ability of the fracture to carry a tensile load. This distinction is necessary to distinguish between highly fractured rock masses and rock that contains a large number of healed fractures. Because the strength of healed fractures can vary from very low to equal to the strength of adjacent core, it is inappropriate to include healed fractures in the basic fracture and RQD logs. The character and representative frequency of healed fractures should be recorded in the Description or Notes columns. If they are low strength, it is probable that natural fractures occurring along the healed joints will indicate the weakness of the rock along the healed joints. If quantitative data on healed joint strength are required, point-load testing should be used to provide a field measurement of anisotropic strength.

8.2.2.7 Core Recovery and Core Losses

The Core Recovery column is used to record the measured amount of core recovered over the measured length drilled for each core run. Measure and record core recovery to the nearest tenth of a foot. The recovery column is divided by solid horizontal lines corresponding to the lines in the Run Number column. Record the actual lengths cored and recovered. Calculate core recovery in the field as a percentage (100% representing complete recovery) if appropriate, but only after the lengths cored and recovered have been recorded. Rubble, redrill, or slough recovered at the top of a core run that was not in place is not counted as recovered core and should be discarded or clearly labelled to avoid subsequent misclassification.

It is not uncommon for some core to slip through the core lifter and to be dropped out of the core tube. This problem frequently indicates a worn or unsuitable core lifter which should be replaced. Core should be represented on the log at the location it occupied in the ground by assigning it to the run in which it was cored; it should not simply be assigned to the run in which it was recovered if it was actually cored in the previous run. This is simple in sections of complete recovery, but requires some interpretation when rock cored during one run is dropped and is recovered during a subsequent run. Dropped core can result in apparent core recoveries exceeding 100 percent if it is not logged correctly. Core recoveries should not significantly exceed 100 percent. Core which was drilled in a previous run can often be identified by marks from the drilling or the core lifter.

Core recovery is presented numerically on the final core log by GOLDLOG2 because graphical presentation of core recovery on a linear scale of limited width is not a sufficiently sensitive indicator of geotechnical conditions.

Core losses are an important indication of potentially poor geotechnical conditions, since they most commonly occur in weak or highly fractured zones which may be important for determining rock mass properties. The core log is completed in a manner which highlights core loss zones. When the core loss exceeds a "significant" level, typically about 0.3 feet, horizontal lines are drawn across all columns that record information about the rock character or properties (description, graphic log, discontinuity data, weathering index, strength index, and point load index), and this interval is labelled "NO CORE". Examples of this procedure are illustrated in Figure 2. No data can be collected from these intervals. It is incorrect to imply that this material is similar to the adjacent material unless there is evidence to support this, in which case the evidence should be included as a note, for example, "core loss due to overfilling barrel."

"NO CORE" intervals should be assigned to their correct locations when there is sufficient evidence from the core or drilling operations to do this. Such evidence might include grind marks on the core or a rubble zone within an otherwise sound core run; the drill rods dropping by an amount equal to the "NO CORE" interval during drilling; or washing away of the beginning of a run in very weak ground. If the location of the interval without core cannot be identified, then it is assigned to the end of the core run. Explanatory notes should be included where it will assist with the interpretation of conditions, for example, "Core lost due to grinding" or "No core due to void."

8.2.2.8 RQD

Rock Quality Designation (RQD) is a modified core recovery in which only the sound core recovered in lengths of greater than four inches (10 cm) measured along the core axis is counted as recovery (Deere and Deere, 1989). RQD is measured for each core run. Record the total length of intact core recovered in lengths greater than 4 inches (10 cm) over the total length of the core run in the RQD column. These numbers are expressed as a percentage to give RQD. RQD can be used as an index of rock quality according to Deere's (1968) original classification:

MODIFIED CORE RECOVERY AS AN INDEX OF ROCK QUALITY

RQD (Percent)	Description of Rock Quality
0 - 25	Very poor
25 - 30	Poor
50 - 75	Fair
75 - 90	Good
90 - 100	Excellent

Because RQD is an index of rock quality, and is not intended to measure the quality of drilling, only natural fractures are considered in RQD measurements. Core breaks caused by the drilling process should be fitted together and counted as one piece (Deere and Deere, 1989). Because drilling and handling fractures can only affect measured RQD if they result in lengths of core of less than 4-inches, RQD is relatively insensitive to the mistaken interpretation of drill-induced fractures as natural fractures in sound rock. As an example, consider a section of rock containing no natural fractures which is fractured at 6-inch to one foot intervals during drilling and handling. Counting these fractures would not significantly reduce RQD, but would increase recorded fracture frequency from 0 fractures/foot to 1-2 fractures/foot.

One special case that may be encountered in measuring RQD is a single fracture parallel to the core axis. Sound core with a single fracture is counted as intact rock and assigned an RQD of 100%. This method is used to avoid biasing the RQD measurement with a single fracture parallel to the drillhole.

The definition of RQD as sound core recovered in lengths of 4 inches or more was originally applied to NX-size (54 mm) core using a double tube core barrel because core size and drilling equipment could influence recovery and breakage of core. Various authors (Heuze, 1971; Goodman, 1980) have proposed varying the length requirements for RQD to twice the core diameter in order to account for these influences. However, after thorough consideration of field experience and current drilling practices, Deere and Deere (1989) conclude that "The 4-inch (100 mm) requisite length, measured at centerline, should be used for all applicable core sizes. The spacing of natural unbounded joints does not change with core size." Improvements in drilling techniques since RQD was first introduced in the 1960's have reduced the influence of core size on recovery and mechanical fracturing during drilling. They conclude that the 4-inch (100 mm) length for a core piece to be counted in RQD is applicable to BQ (36.5 mm), NQ (47.6 mm), HQ (63.5 mm), PQ (85 mm), 4-inch (100.8 mm) and 6-inch (151.6 mm). They recommend noting on the core log for B-size core that both core recovery and RQD values may be slightly lower than for larger core. They consider smaller core sizes (A and E) too small to be used for RQD.

The recommendations of Deere and Deere should be followed in measuring RQD, including:

- use 4-inch (10 cm) requisite length, measured at centerline, for all applicable core sizes
- note any variations from this standard definition on each page of the core logs
- for B size (or smaller) core, note on each page of the core logs that RQD values may be lower than for larger core

RQD is valid only for sound core and should not be used for very poorly indurated materials such as clays and weak claystones. In these cases, the letters N/A (Not Applicable) should be entered into the RQD column.

8.2.2.9 Fractures Per Foot

The Fractures Per Foot column is used to record the number of natural fractures in each one foot interval. If more than ten naturally occurring fractures are counted in a one foot interval, then record >10 in the Fractures Per Foot column. Like RQD, the fracture log is not applicable to very poorly indurated material.

Because the fracture log is maintained for one foot intervals, it is a much more sensitive indicator of fracturing and broken zones than RQD, which is only measured over each core run.

8.2.2.10 Discontinuity Data - Description and Graphic Log

The orientations and physical characteristics of discontinuities are important parameters in characterizing a rock mass and should be recorded for each significant natural discontinuity in the core. The standard core logging form is designed to facilitate recording these data in the Discontinuity Data columns.

When similar natural fractures occur regularly along pre-existing weakness planes such as bedding or foliation, it is not necessary to record the orientation and characteristics of each fracture individually. An explanatory note such as "unless otherwise noted fractures to 274 feet are along foliation; planar; smooth" should be included to eliminate the need to repeat the description for each fracture. Only fractures which do not meet these criteria then need to be described individually, although the location and dip of all fractures should be recorded in the Discontinuity Graphic Log column.

Discontinuity Type and Surface Description

Record the type of discontinuity and its surface characteristics using the following system of mnemonics, which is included on the logging form.

DISCONTINUITY TYPE	DISCONTINUITY SHAPE	SURFACE ROUGHNESS	INFILLING
J - Joint	PL - Planar	P - Polished	CA - Calcite
F - Fault	C - Curved	K - Slickensided	CL - Clay
S -Shear	U - Undulating	SM - Smooth	Fe - Iron Oxides
B - Bedding	ST - Stepped	R - Rough	
FO - Foliation	I - Irregular	VR - Very Rough	

Due to space limitations, the list of mnemonics cannot be comprehensive, and has been limited to five types in each category. The most commonly used terms are included, although many other terms such as vein and contact have not been included. Additional spaces are provided on the drilling log for user-specified mnemonics to help overcome these limitations. These mnemonics should be recorded on the field log and explained in accompanying text.

Figure 9 illustrates typical discontinuity shape and roughness profiles. A more quantitative description of discontinuity roughness that may be appropriate for projects where shear strength of discontinuities is a concern is illustrated in Figure 10. Joint condition ratings applicable to Bieniawski's RMR system and Barton's "Q" system of rock mass classification are tabulated in Figure 4 (Hoek & Brown, 1980). Quantitative estimates of these values should be included for representative surfaces in the Type and Surface Description column if the core logs are to be used as a basis for quantitative rock mass classification.

The type and thickness of any infilling or staining should be recorded using user-specified mnemonics or suitable descriptions. If there is insufficient space in the Type and Surface Description column for a complete description of the joint surface, the scale of the log should be increased or the notes column can be used to take care of occasional data overflow.

Discontinuity Graphic Log

The Graphic Log column is used to sketch all naturally occurring discontinuities in the drill core. This information is plotted manually on the final logs produced by GOLDLOG2, so it is recorded graphically rather than numerically. If the Fractures Per Foot is less than or equal to ten, then all fractures should be drawn at the location in the rock core where they occur. This is easily accomplished by marking the beginning and end of a fracture at the corresponding locations on the graphic log, then connecting the end points to sketch the fracture. Since the width of the Graphic Log column is not in scale with the width of most drill core (it is wider to allow room to sketch all fractures) a protractor should not be used to sketch the fractures at true dip angles, as this would result in exaggerated lengths for the fractures sketched. If the Fractures Per Foot is greater than ten, then sketch any predominant fracture orientations and cross-hatch over the entire area in the Graphic Log column to indicate very fractured rock core.

Discontinuity Dip With Respect to Core Axis

Measure and record numerically the dip with respect to the core axis of each significant natural discontinuity, as illustrated in Figure 4. Note that for vertical holes, the recorded value is the complement of the true dip. Individual fracture orientations cannot generally be measured in broken and crushed zones, although in strongly foliated rock fracturing may develop preferentially along foliation and this should be recorded. A separate column is not provided for recording this data on the field log. It should be recorded within or immediately adjacent to the Graphic Log column in such a manner that it is clear which fracture on the Graphic Log record the measured orientation applies to. This orientation data is plotted graphically in a separate column on the final logs.

8.2.2.11 Weathering/Alteration Index

The Weathering Index column is used to record the weathering classification in accordance with the ISRM recommended classification system which is shown in Figure 4. Changes in the Weathering Index are indicated by a solid horizontal line at the point of change for an abrupt change, or a solid slanting line covering the range of weathering change. Unfortunately, the ISRM weathering classification is inadequate for the commonly encountered condition where weathering is confined to the immediate vicinity of fracture surfaces. Also the descriptions corresponding to each weathering classification are relatively severe so that the system is an insensitive indicator of weathering condition over the slight to moderate range. Use the notes column as necessary to clarify the condition of weathered rock.

On many projects, particularly for mining clients, propylite or argillization resulting from hydrothermal alteration can modify rock strength in much the same manner as weathering reduces the strength of near-surface rocks. Conversely, silicification or potassic alteration may increase rock strength. On these projects, the intensity of alteration may be a more important indicator of rock strength than weathering. However, such projects are not a sufficient proportion of our rock coring projects to justify inclusion of a separate column to log alteration.

GOLDLOG2 provides the compromise of being able to relabel the Weathering Index column as Alteration Index on any new sheet of the log. The classification labels on the log are then automatically modified to reflect alteration rather than weathering. This option enables the column to be used to indicate weathering at the top of the drillhole and alteration at depth. There is no ISRM standard for degree of alteration, but geologists on mining projects will typically use a five or six category alteration classification system that should be incorporated into the geotechnical logging if alteration affects strength, and should be defined in the report. If the alteration column is used to indicate a type of alteration that increases the rock strength, such as silicification, then the plot scale should be reversed to maintain the convention that more shading on a graphic log indicates weaker rock or more fracturing. The option to reverse the plot scale is offered if the weathering index is changed to an alteration index.

It is not unusual to have multiple types of alteration, such as both argillic and silicic alteration, present simultaneously, and for the strength of the rock to be a function of the degree of argillic and/or silicic alteration. The most suitable method for documenting such complex alteration should be determined for each case individually based on such factors as the character of the alteration, its influence on rock properties, and the purpose of the geotechnical documentation. If both types of alteration significantly influence the mechanical character of the rock, a dual alphanumeric classification system (e.g., A1, S5 or A2, S3) should be used in place of the graphic log. In other cases, the alteration that is of most importance for the geotechnical evaluation could be recorded in the alteration column, while the alteration of secondary importance could be recorded as notes or in an optional column.

8.2.2.12 Strength Index

The Strength Index column is used to record the estimated strength of intact rock material strength using the ISRM recommended classification system shown in Figure 4. Any change in the Strength Index should be defined by a solid horizontal line at the point of change. Point-load tests are commonly performed as a standard part of geotechnical core logging. Field estimates of intact strength should be modified to reflect the results of point-load tests and laboratory testing when the final corehole logs are prepared. Strength Index is plotted graphically on final logs to provide a continuous record of the strength of the core.

8.2.2.13 Point Load Index

Point load tests are commonly performed as a standard part of logging the geotechnical characteristics of rock core. They provide a quantitative measure of rock strength which is necessary to bridge the gap between qualitative description of rock characteristics and the quantitative requirements of engineering evaluation. Every effort should be made to test samples which are representative of the rock mass, rather than concentrating testing on samples that are easiest to test. Point load test data are recorded on a separate data recording form. Results for each valid test are plotted on the final geotechnical drillhole logs according to the ISRM recommended strength classification system. Since both axial and diametral tests are performed in order to provide a measure of anisotropy, different symbols are used to represent axial and diametral tests. The location and type of each valid test should be recorded on the field log by plotting the symbol shown on the log at the depth of the test sample.

8.2.2.14 Notes, Water Levels, Instrumentation

The final column on the log is used to record pertinent information on the drilling operation and geotechnical conditions which does not belong in or cannot be fitted into the preceding sections of the log. The following data should always be recorded:

- Casing size and depth
- Core size
- Bit type
- Type and length of core barrel
- End of drilling each day or shift
- Drilling fluid type and losses
- Final depth of hole
- Completion date
- Water level at time of completion

Other items that should be included when relevant include:

- Water levels measured during drilling, such as at the start and end of each day or shift, and the date of measurement
- Water or mud returns
- Details of instrumentation
- Drilling information, such as penetration rates and descriptions of drilling problems
- Permeability test locations and results
- Any information that may assist in understanding geotechnical conditions or the condition of the core, for example, locations where drill rods drop, core is ground, or the core barrel is overfilled.

8.2.3 Optional Data Column

GOLDLOG2 permits the addition of an optional extra column immediately right of the Point Load Index column. This optional column will take space from the Notes, Water Levels, Instrumentation column. The user can specify the column heading, column width, and data to be input into the column, including locations of horizontal lines across the columns. The purpose of this column is to record information or test results that may be particularly important to a specific project or region, such as permeability test results, oriented core run locations and test results, the presence and condition of ice, secondary alteration, geophysical borehole logging results, penetration rates, etc. The Notes column should be subdivided manually for recording this additional data in the field if the optional extra column will be used on the final log.

8.2.4 Variations of the Standard Geotechnical Logging Form

The standard Record of Drillhole Form has been designed to facilitate rock core logging for geotechnical purposes and to accommodate the needs of most geotechnical projects. Personalized logging forms are generally not encouraged because the standard form provides consistency in logging procedures and presentation format. However, it is recognized that unique conditions, client requirements, or drillhole documentation for purposes that are not primarily geotechnical, may require some modification to the standard logging form. Such variations are permitted only at the direction of the Project Manager and should be documented on a Field Change Request (see Section 8.6). An example of an alternative logging form designed for use in a hydrogeologic investigation where rock strength, weathering, and alteration were not considered to be pertinent is shown is Figure 11. It is important that as much of the standard logging form as is possible be retained on the modified log, and that the standard rock core logging procedures be complied with for these standard portions of the log.

8.2.5 Summary Geotechnical Logs for Mining Projects

Geotechnical core drilling should be performed under the direction of a qualified geotechnical engineer or geologist, and detailed geotechnical logs should be prepared for all critical elements of rock engineering projects. However, in some circumstances it will not be possible or justifiable to undertake detailed geotechnical logging of all core drilling on a project. This is commonly the case during the early exploration stages of mining projects. Summary geotechnical logs may be appropriate to enable a general characterization of geotechnical conditions in cases such as the following examples:

- During pre-feasibility exploration drilling, the feasibility of mine development and potential pit limits may not be adequately defined to justify the expense of detailed geotechnical logging.
- In a mine pit slope stability evaluation, it may not be an efficient use of available resources to develop detailed geotechnical logs for the central mineralized zone if the geotechnical conditions at the pit limit will be significantly different due to structural control of mineralization, alteration zoning, or other factors.

- For potential underground mines, it may not be necessary or appropriate to perform detailed geotechnical logging of waste rock at substantial distances from potential mine development or production stopes.
- Geotechnical engineers may have a limited time available to characterize geotechnical conditions from a large quantity of exploration core that is already boxed.
- Exploration geologists may wish to incorporate some basic geotechnical data collection into their standard core logging procedures but may not have the resources to complete detailed geotechnical logging of all core.

In such cases, summary geotechnical logging may be appropriate for evaluating the distribution of geotechnical units and conditions that will be encountered during development of less important interim pit slopes, while detailed geotechnical logging could be used for characterizing conditions in critical areas such as representative locations in the vicinity of final pit slopes or important fault zones. During the early stages of exploration, it is preferable to have limited geotechnical data from a large number of locations to characterize the distribution of geotechnical units and to help identify potential geotechnical problems, rather than having detailed geotechnical information from few locations that may not be representative of critical areas or important geotechnical units.

Summary geotechnical logging can provide a suitable geotechnical database that can be used in conjunction with the geologic model to identify important geotechnical issues and to define a program of detailed geotechnical investigation for support of feasibility-level or final mine design. Detailed geotechnical logging is usually performed on geotechnical coreholes and oriented coreholes that are located to investigate geotechnical and structural conditions in critical areas to support development of detailed design recommendations.

While details of summary geotechnical logs should be developed based on the site conditions and specific requirements of a project, the example summary log that has been used for mining projects and is shown in Figure 12 should be suitable for many applications. Geologic logs that document lithology, core intervals, fault zones, alteration details, and other pertinent data should be used in conjunction with the geotechnical summary logs. In general terms, summary geotechnical logs should document the intensity and character of fracturing, and intact rock strength. Fractures are not documented individually, although typical surface characteristics and relative orientations of representative discontinuities are recorded. Summary geotechnical logging typically focuses on documenting quantitative geotechnical data that can be readily evaluated and analyzed manually or using a spreadsheet. The following paragraphs describe how a summary geotechnical log should be completed.

Depth intervals can correspond to core runs if the summary logs are prepared immediately after coring, in conjunction with geological logs. However, depth intervals could also be selected to correspond to intervals of similar geotechnical characteristics if this is more appropriate. Length of the interval is calculated as the difference of the depth intervals.

The basic geologic unit is recorded to facilitate evaluation of geotechnical parameters according to geology, but no detailed description of geology is included because this is available on the geologic logs. Recovered core and modified core recovery (sound core in lengths greater than 4 inches) are recorded for each depth interval to enable calculation of core recovery and RQD as percentages. The number of natural fractures in the depth interval is recorded to enable calculation of the fracture index.

No weathering index is included, since summary geotechnical logs are most commonly applied to mining projects where weathering is not a primary consideration. Two columns are provided to record alteration indexes, since this is a common requirement in zones of hydrothermal alteration associated with mineralization. The strength index is estimated according to the ISRM field identification procedure.

Discontinuity data recorded for representative or prominent structures includes the type of dicontinuities, their orientation relative to the core axis, and typical surface characteristics. Depending on project requirements, surface characteristics could be descriptive terms listed in Figure 9, or one of the quantitative Joint Condition Rating systems documented in Figures 4 and 10 if the summary geotechnical logs will be used as a basis for quantitative rock mass classification. Unlike detailed geotechnical logging, each fracture is not documented individually or recorded graphically

The comments column is used to record any additional information that may be useful in interpreting the geotechnical data, for example, the distribution of fault zones, or the character of crushed or broken zones.

8.2.6 Minimum Geotechnical Data Collection During Exploration Coring

During pre-feasibility exploration coring, valuable geotechnical information can be collected with minimal effort and time in conjunction with geologic logging. Reliable measurement of RQD and ISRM field strength index should be within the capabilities of any competent geologist who is provided with proper instructions. Nothing less than this minimal geotechnical information should be collected at any time that the expense of coring is incurred.

These RQD and strength data should be incorporated into the geologic database to enable correlations based on geologic parameters such as lithology, mineralization, and alteration. While these minimal data will not generally provide sufficient information for a detailed geotechnical evaluation, they will provide a quantitative basis to support a preliminary evaluation and to develop a focused geotechnical data collection program to support a more detailed engineering evaluation.

8.3 Boxing of Core

8.3.1 When to Box Core

The core should be carefully transferred to the core box after the core has been logged in the tube liner, split tube, or V-shaped core tray. Mark the core with two continuous, parallel lines to facilitate identification of incorrectly boxed core, samples that have been returned to the core box incorrectly, or core that has suffered abuse. Use the following standard navigational convention: when looking down the core axis, make a red line on the left (red...port...left) and a green line on the right (green...starboard...right). Ideally, all geotechnical logging should be completed prior to transferring the core to the core box, since some damage to the core is almost certain to occur during the transfer. In practice, it will not always be justifiable to delay drilling while geotechnical logging is completed, so the tube liners or inner tube will have to be returned to the drillers in a timely manner to prevent drilling delays. As a minimum, complete the core recovery, RQD, and fracture log measurements prior to transferring the core to the core box.

8.3.2 Acceptable Core Boxes

Cardboard core boxes are frequently used for storage of small to medium diameter core under favorable conditions, that is, dry climate and storage conditions with limited transportation and handling requirements. For larger core, wet conditions, or projects where the core will be transported over longer distances or rough terrain, more durable wooden, metal, or plastic core boxes with securely fitting lids should be used. The core should fit snugly into the core box to minimize damage to the core during handling and transportation. Additional packing will generally be required if the core is to be shipped or transported without continuous monitoring or supervision.

8.3.3 Breaking the Core for Boxing

It will usually be necessary to break the core in order to box it. The amount of core breakage for boxing should be minimized by carefully determining the points at which the core should be broken to fit neatly into the box. The core should then be broken cleanly at these points using a suitable method which minimizes damage to the core such as:

- Cutting the core with a knife for very low strength claystones and shales
- Performing a diametral point load test at the point
- Breaking the core with a sharp blow from a geological hammer
- Using a hammer and chisel to break the core

The force required to break the core should be used to help evaluate the rock strength. An "X" drawn with a permanent black marker should be placed across all artificial core breaks.

8.3.4 Placing Core in Box and Labelling Box

The core should be completely cleaned with clean water prior to placing it in the core box. Each core box is placed with its label at the left end. The top of the core is placed in the top left corner of the box, and the core is boxed from left to right, top to bottom of the box - "just like reading a book." Wooden or plastic core spacers with footages labelled by indelible marking pen should be used to mark depths at the start and end of each core box, the beginning and end of each core run, intervals of core loss, and the location of samples removed for testing or other purposes. These spacers also help to keep the core intact during transportation. One pound polyethylene foam is recommended as a spacer when maintenance of core quality is critical, as it is on most geotechnical coring projects. This spacing material is elastic and when cut slightly oversize it can be used to wedge the core securely in place. An indelible marking pen should be used to mark any breaks caused by handling or point load testing that could subsequently be mistaken for natural fractures. Each core box and lid should be indelibly labelled with the following information:

- Project name and/or number
- Drillhole number
- Core size
- Box number
- Depth at start and end of core

8.4 Photographic Documentation

Color core photography provides a permanent record of the condition of the core at the time of recovery and is a standard part of core documentation for all rock core logging projects. Photographs show details and characteristics that can not be easily recorded or conveyed on drillhole logs. They are convenient for reviewing the condition and character of the core when preparing final logs in the office, and are invaluable for review by personnel who do not have the opportunity to inspect the actual core. They also provide permanent visual documentation of core that may be destroyed for assaying or metallurgical testing, or may be lost. 35 mm color prints provide the most convenient format for review and inclusion in reports. Color slides have the advantage that they can be projected at natural scale for detailed review.

Core photographs should be taken soon after the core is boxed, preferably before it is damaged by handling or point load testing, and before and core deteriorates due to slaking or desiccation. Core spacers should be adjusted to true locations to account for dropped core prior to photographic documentation. The core can be either wet or dry when photographed depending on which condition best shows the rock structure, provided the core is in the same condition in all photographs. Color control patches and a grey scale should be included in each print photograph where rock classification or characteristics may depend on color, such as when weathering or alteration is important, so that prints can be color corrected if necessary.

Each core photograph should include a label defining the project, drillhole number, and core interval. This can be achieved conveniently by including the label on the core box lid in the photograph or by labelling the top of the core box with an indelible marker. All core spacers must be photographed at their correct locations and must be readable in the photograph. A scale should be included in all photographs. Photographs should be taken perpendicular to the core box; it is frequently more convenient to carefully tilt the core box for photographing than to locate the camera vertically above a horizontal core box. A wide-angle lens may facilitate photographing long core boxes. Using a hand-held 35 mm camera to photograph core boxes that are propped up may be adequate for smaller projects. For large projects it will be more convenient, and will produce better quality photographs, if a suitable frame is constructed to hold the core boxes and the camera is mounted on a tripod. A reflex camera is preferable to eliminate parallax errors.

Subdued daylight provides the best lighting conditions for core photography. Flash or flood lights may be necessary in adverse lighting conditions. Regardless of the lighting used, every effort should be made to maintain consistent lighting conditions for all photographs. Ensure the f stop is set correctly for the core, not for the core box or other surroundings. This is particularly important for dark cores when photographed in light colored core boxes or surroundings.

While routine core photography to document the entire core is completed after the core is boxed, additional photographs should be taken to document interesting features or particular characteristics of the core. This could include photographing sensitive core in the split tube or tube liner prior to handling; taking additional photographs of sensitive core subsequent to deterioration or desiccation; and close up photographs of shear zones or fracture surfaces. All photographs must include a scale and adequate labeling so that they are readily identifiable.

8.5 Sample Preservation

Proper preservation of samples for laboratory testing is critical for meaningful laboratory test results. If samples will be stored for more than one to two weeks before testing, or if the sampled material is susceptible to desiccation (typically weaker materials with moderate to high water contents, such as clays, highly altered or weathered rock, fault gouge, etc.) then test samples should be preserved using the following procedure:

1. Wrap sample in plastic wrap or plastic bag.
2. Wrap sample in aluminum foil and indicate which end of core is up.
3. Label sample using indelible marker on aluminum foil and indicate which end of core is up.
4. Coat sample completely with hot wax by dipping and rolling in a pan of molten wax.
5. Attach permanent label to preserved sample.

The wax coating serves to preserve the moisture content, and to provide support and protection against damage during handling and transportation. If samples to be tested are not susceptible to desiccation (typically stronger rock with low water content) then wrapping in two or more layers of plastic wrap, or use of a heavy weight ziplock plastic bag, and strapping with duct tape to provide reinforcement and protection, will be sufficient for most samples. Sensitive samples should be packed in PVC pipe or other similar protective material before boxing for shipment. Samples should not be allowed to freeze in cold weather and appropriate measures should be taken to prevent freezing. Such measures include storing samples in an insulated ice chest or in a heated field vehicle. Samples should be packed with suitable packing material and shipped in a sturdy box to prevent damage during shipping.

For particularly important projects involving sensitive core, more care may be required for sample preservation and transportation. This could include shipping the samples in a sealed triple tube liners or using disposable lexan inner tubes or tube liners for collecting and shipping the core. In these cases, the tubes or tube liners should be capped at both ends and sealed with wax or polypropylene tape. With disposable lexan tubes, partially filled tubes should be cut away prior to capping.

8.6 Field Change Request

Variations from established procedure requirements may be necessary due to unusual field situations or unique client requirements. The Project Manager may delegate authority to the onsite Geologist/Field Engineer to initiate variations as necessary to respond to such situations; however, all variations from established procedures shall be documented on Field Change Request (Figure 13) and verbally reported to the Project Manager within 24 hours. The Field Change Request shall be submitted to the Project Manager and QA Manager for formal review and approval within 2 working days. Disapproval of a Field Change Request shall require re-performance of the logging activity or other appropriate resolution as directed by the Project Manager.

All completed Field Change Requests shall be maintained in the project records.

RECORD OF DRILLHOLE

Sheet of

PROJECT:	DRILLING METHOD:	DATUM:	COLLAR ELEV:
PROJECT NO:	DRILLING DATE:	COORDINATES N:	E:
LOCATION:	DRILL RIG:	AZIMUTH:	INCLINATION:

J-Joint, F-Fault, S-Shear, B-Bedding, FO-Foliation, PL-Planar, C-Curved, U-Undulating, ST-Stepped, I-Irregular, P-Polished, K-Slickensided, SM-Smooth, R-Rough, VR-V.Rough, Fr-Fracture, Fe-Iron Oxides, CA-Calcite, CL-Clay

● Axial ■ Diametral

DEPTH SCALE (FEET)	ROCK TYPE DESCRIPTION	GRAPHIC LOG	ELEV DEPTH (FT)	RUN NO.	CORE RECOVERY	RQD	FRACTURES PER FOOT	DISCONTINUITY DATA TYPE, SURFACE DESCRIPTION, AND DIP w/t CORE AXIS	GRAPHIC LOG	ISRM WEATHERING INDEX FR SW MW HW CW	ISRM STRENGTH INDEX R6 R5 R4 R3 R2 R1	POINT LOAD TESTS	NOTES WATER LEVELS INSTRUMENTATION

SCALE:	LOGGED:	UCS (psi) R1 150, R2 725, R3 3,500, R4 7,500, R5 15,000, R6 35,000
DRILLING CONTRACTOR:	CHECKED:	Golder Associates
DRILLER:	DATE:	

FIGURE 1
RECORD OF DRILLHOLE
TP-1.2-2

RECORD OF DRILLHOLE (EXAMPLE)

Sheet 1 of 1

PROJECT: XYZ Power
PROJECT NO: 893 1999
LOCATION: Mohawk Mtn.

DRILLING METHOD: NQ Wireline
DRILLING DATE: 21 Aug 89
DRILL RIG: Longyear 44

DATUM: MSL
COORDINATES N: 68345 E: 231112
AZIMUTH: N/A

COLLAR ELEV: +2.0
INCLINATION: -90°

Discontinuity codes: J-Joint, F-Fault, S-Shear, B-Bedding; FO-Foliation, PL-Planar, C-Curved, U-Undulating; ST-Stepped, I-Irregular, P-Polished, X-Slickensided; SM-Smooth, R-Rough, VR-V.Rough, Fr-Fracture; CA-Calcite, CL-Clay, CT-Contact, RD-Redrilled, Fe-Iron Oxides

Point load tests: ● Axial ■ Diametral

Rock type

Depth (feet)	Description
0-3.0	Compact, mod. brown (5YR 4/4) F-M SAND, some gravel COLLUVIUM
3.0-11.5	Highly weathered, grayish red (5YR 4/2) basalt clasts (medium strong) in compact basaltic silty sand matrix. WEATHERED BASALT
11.5-23.0	Slightly weathered to fresh, dusky yellowish brown (10YR 2/2) strong vesicular BASALT, zeolite infilling of vesicles local FeOx stained fractures at 19.0' moist (GRANDE RONDE BASALT)
23.0-37.0	Fresh, dusky yellowish brown (10YR 2/2) aphanitic strong-very strong BASALT (GRANDE RONDE BASALT)
30.0-32.0	NC — No core
32.0-33.0	Shear zone containing soft, slickensided gouge
33.0-37.0	Zone of closely spaced (≥1/4") imbricate shears
EOH 37.0	

Core runs

Run No.	Core recovery	RQD	Fractures per foot	Discontinuity data (type, surface description, and dip wrt core axis)	ISRM weathering index	ISRM strength index
1	4.5/5.0	N/A	N/A		HW	R3*
2	2.1/2.5	N/A	N/A		HW	R3*
3	2.3/2.5	1.5/2.5	0		SW	R4
4	2.5/2.5	2.0/2.5	1, 0	J.U.SM (43°)	SW	R4
5	2.5/2.5	2.0/2.5	2, 0	J.U.SM, Fe stained (45°, 50°)	SW	R4
6	5.0/5.0	4.5/5.0	1, 1, 2, 1, 0	16.0-22.0 J.U.SM (45°, 40°, 80°)	SW / 30' FR	R4
7	4.8/5.0	4.6/5.0	0, 0, 0, 1, 2	25.0-30.0 J.PL.SM (73°)	FR	R4 to R5
8	3.0/5.0	0.3/5.0	2, 5, 7	80°, 85°, 80°, 70°, 75°; 30.0-32.0 S.U.SM 80-75°	67', 60', 55' HW	R4 to R5
	No core				No core	
9	N/A	N/A	N/A		CW	R0
9	4.5/5.0	1.6/5.0	>10, 8	32.0-33.0 F.PL.P/K, slick rake direction 20° to fault dip direction (65°)	HW	R2 to R3
9			4, 3	33.0-37.0 S.U.SM (85-80°, 80°)	FR	R4

Notes, water levels, instrumentation

Rotary drilled with tricone bit to 30.0 ft. casing set to 3.0 ft.

* 3.0-11.5 R3 applies to basalt clasts only

Cored using NQ wireline barrel and face discharge bit

Boring completed 21 Aug 1989

No groundwater encountered

UCS (psi): R1 – 150; R2 – 725; R3 – 3,500; R4 – 7,500; R5 – 15,000; R6 – 35,000

SCALE: 1" = 5'
DRILLING CONTRACTOR: DTH Inc.
DRILLER: D. Decimal

LOGGED: D. Findley
CHECKED:
DATE:

Golder Associates

FIGURE 2
RECORD OF DRILLHOLE (EXAMPLE)

RECORD OF DRILLHOLE F-2

PROJECT: RW Beck/Head Work/WA
PROJECT NO: 933-1371
LOCATION: Green River, WA

DRILLING METHOD: NQ Wireline
DRILLING DATE: 10/4/94
DRILL RIG: B-53

DATUM: MSL
COORDINATES N: 1,423,650.4
AZIMUTH: N/A

COLLAR ELEV: 898.0
E: 967,357.4
INCLINATION: -90°

Legend: J-Joint, F-Fault, S-Shear, B-Bedding; FO-Foliation, PL-Planar, C-Curved, U-Undulating; ST-Stepped, I-Irregular, P-Polished, K-Slickensided; SM-Smooth, R-Rough, VR-V.Rough, Fr-Fracture; CA-Calcite, CL-Clay, CT-Contact, RD-Redrilled, Fe-Iron Oxides. ● Axial ■ Diametral

Column headings: DEPTH SCALE (FEET) | ROCK TYPE: DESCRIPTION | GRAPHIC LOG | ELEV / DEPTH (FT) | RUN NO. | CORE RECOVERY | RQD (80 60 40 20) | FRACTURES PER FOOT (2 4 6 8 10) | DISCONTINUITY DATA: DIP w.r.t. CORE AXIS (0 30 60 90) | TYPE AND SURFACE DESCRIPTION | GRAPHIC LOG | WEATHERING INDEX (FR SW MW HW CW) | STRENGTH INDEX (R6 R5 R4 R3 R2 R1) | POINT LOAD INDEX (psi) (R6 1600, R5 600, R4 300, R3 150, R2 60, R1 30) | NOTES, WATER LEVELS, INSTRUMENTATION

Depth (ft)	Description	Elev / Depth (ft)	Run No.	Core Recovery	Discontinuity Type and Surface Description	Notes
30–31.2	Fresh to slightly weathered, grayish red (5R 4/2), medium strong, very coarsely crystalline ANDESITE				J, PL, VR 26°; J, PL, VR 26°; J, PL, VR 26°; J, PL, VR 22°	Note: Breaks on graphic log are natural breaks. There are abundant drill breaks throughout run
31.2–33.7	Fresh to slightly weathered dark gray (N3) and brownish gray (5YR 4/1) porphyritic, medium strong to strong, ANDESITE LAPALLI TUFF local secondary pyrite phenocrysts	31.2	3	85	CT, RD 90°; J, PL, R 22°; J, PL, VR 55°; J, C, VR 62°; J, PL, VR 25°; J, PL, VR 55°; J, PL, VR 10°	Abundant drill breaks; Note: Core loss due to inability of catcher to pick up low RQD rock
33.7–34.4	No Core	864.3 / 33.7 – 863.6			No Core	0929 Finish Run 3
34.4–35.6		34.4 – 862.4	4	100	J, PL, R, CA 40°; J, I, VR, CA 55°; J, PL, R, CA 90°	35.1' Redrill abundant Silt and Fe Ox coatings. Driller noted drilling different at ~35.4'.
35.6	Drillhole completed 4 Oct. 94, Total Depth: 35.6 ft.	35.6				

SCALE: 1" = 1'
DRILLING CONTRACTOR: PC Exploration
DRILLER: T. Cole

LOGGED: F. Mocker
CHECKED: D. Findley
DATE: 7 Nov 94

Golder Associates

FIGURE 3
GOLDLOG 2 RECORD OF DRILLHOLE
TP-1.2-2

TION
S

(FR)	slight discoloration on major discontinuity surfaces.	
Slightly Weathered (SW)	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than in its fresh condition.	II
Moderately Weathered (MW)	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework or as corestones.	III
Highly Weathered (HW)	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones.	IV
Completely Weathered (CW)	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	V
Residual Soil (RS)	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

JOINT CONDITION RATING

BARTON'S "Q" SYSTEM

Joint Roughness (Jr)	
Condition of Joints	**Rating**
Noncontinuous joints	4.0
Rough and wavy	3.0
Smooth and wavy	2.0
Rough and planar	1.5
Smooth and planar	1.0
Slick and planar	0.5
Filled discontinuities	1.0

Joint Alteration (Ja)	
Condition of Joints	**Rating**
FILLING AND WALL-ROCK ALTERATION, ESSENTIALLY UNFILLED	
Healed joints	0.75
Staining only, *no alteration*	1.0
Slightly altered joint walls	2.0
Silty or sandy coatings	3.0
Clay coatings	4.0
FILLING AND WALL-ROCK ALTERATION, FILLED JOINT	
Sand or crushed rock filling	4.0
Stiff clay filling less than 5mm thick	6.0
Soft clay filling less than 5mm thick	8.0
Swelling clay filling less than 5mm thick	12.0
Stiff clay filling more than 5mm thick	10.0
Soft clay filling more than 5mm thick	15.0
Swelling clay filling more than 5mm thick	20.0

ST
NATION

JOINT CONDITION RATING

BIENIAWSKI'S RMR SYSTEM

Condition of joints	Rating
Very rough surfaces Not continuous No separation Fresh (Hard) joint wall rock	25
Slightly rough surfaces Separation <1mm Slightly weathered (Hard) joint wall rock	20
Slightly rough surfaces Separation <1mm Highly weathered (Soft) joint wall rock	12
Slickensided surfaces —or— Gouge <5mm thick —or— Separation 1–5mm	6

S1	Very soft clay	Easily penetrated several inches by fist
S2	Soft clay	Easily penetrated several inches by thumb
S3	Firm clay	Can be penetrated several inches by thumb with moderate effort
S4	Stiff clay	Readily indented by thumb but penetrated only with great effort
S5	Very stiff clay	Readily indented by thumbnail
S6	Hard clay	Indented with difficulty by thumbnail
R0	Extremely weak rock	Indented by thumbnail
R1	Very weak rock	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife
R2	Weak rock	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer
R3	Medium strong rock	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of geological hammer
R4	Strong rock	Specimen requires more than one blow of geological hammer to fracture it
R5	Very strong rock	Specimen requires many blows of geological hammer to fracture it
R6	Extremely strong rock	Specimen can only be chipped with geological hammer

Note: Grades S1 to S6 apply to cohesive soils, for example, clays, sl combinations of silts and clays with sand, generally slow draini rounding of the strength values has been made when convertin

GRAIN SIZE CLASSIFICATI

GRAIN SIZE CLASSES AND SILICICLASTIC ROCKTYPES

	boulders	conglomerates (rounded clasts)
256 mm	cobbles	and
64	pebbles	breccias (angular clasts)
4	granules	
2 mm	v. coarse	
1	coarse	
500µm	SAND medium	SANDSTONE
250	fine	
125	v. fine	
63 microns	v. coarse	
32	coarse	MUDROCKS
16	SILT/SILTSTONE medium silt	other types: mudstone shale marl slate
8	fine silt	
4 microns	CLAY/CLAYSTONE	

…PAR>⅔ TOTAL FELDSPAR		POTASH FELDSPAR ⅓—⅔ TOTAL FELDSPAR			PLAGIOCLASE FELDSPAR>⅔ TOTAL FELDSPAR						LITTL…
					POTASH FELDSPAR >10% TOTAL FELDSPAR	POTASH FELDSPAR<10% TOTAL FELDSPAR					CHIEFL… PYROX… AND/O… OLIVIN…
						SODIC PLAGIOCLASE		CALCIC PLAGIOCLASE			
QUARTZ <10% FELDSPATHOID <10%	FELDSPATHOID >10%	QUARTZ >10%	QUARTZ <10% FELDSPATHOID <10%	FELDSPATHOID >10%	QUARTZ >10%	QUARTZ >10%	QUARTZ <10% FELDSPATHOID <10%	QUARTZ <10% FELDSPATHOID <10%		FELDSPATHOID >10% PYROXENE >10%	
…NDE, BIOTITE, PYROXENE, MUSCOVITE …IBOLES, AEGIRINE, CANCRINITE, TOURMALINE		CHIEFLY: HORNBLENDE, BIOTITE, PYROXENE ALSO: SODIC AMPHIBOLES, AEGIRINE			CHIEFLY: HORNBLENDE, BIOTITE, PYROXENE (IN ANDESITE) ALSO: PYROXENE FELDSPATHOID SODIC AMPHIBOLES			CHIEFLY: PYROXENE, URALITE, OLIVINE ALSO: HORNBLENDE, BIOTITE, QUARTZ, ANALCITE, AEGIRINE, SODIC AMPHIBOLES			CHIEFLY: SERPENTI… ALSO: HORNBLENDE…
15	20	20	25	30	20	20	25	50		60	95
60 4 17 0 2 7 2 9 1 8 3 7 4 2 5 1	56 0 19 2 2 9 1 6 0 6 2 0 8 5 5 3	66 8 15 8 2 3 1 3 1.0 2 8 3 7 4 2	57 0 17 1 3 4 3 6 2.3 5 4 4 7 3 7	54 1 21 0 1 8 5 3 1 1 3 2 6.2 5 9	65 3 16 1 2 1 2 3 1 7 3 9 3 8 2 7	61 0 16 2 2 5 3 8 2 8 5 4 3 4 2 1	58 2 17.0 3 2 3 7 3 5 6.3 3.5 2 1	48 6 16 8 4 8 6.0 5 1 8 9 3 7 1 9		47 4 15 4 4 9 5 4 5 0 9 7 3 8 3 5	41 1 4 8 4.0 7.1 32.2 4.4 0.5 1.0
…NITE …UARTZ SYENITE—a little quartz …LKALI SYENITE—no plagioclase except albite PULASKITE—a little nepheline NORDMARKITE—a little quartz LARVIKITE—with "blue" feldspar SHONKINITE—abundant FeMg minerals	NEPHELINE SYENITE LEUCITE SYENITE—pseudoleucite only feldspathoid SODALITE SYENITE—sodalite only feldspathoid FOYAITE—abundant feldspar MALIGNITE—abundant FeMg minerals DITROITE—with nepheline and sodalite	QUARTZ MONZONITE (ADAMELLITE)	MONZONITE	NEPHELINE MONZONITE	GRANODIORITE	QUARTZ DIORITE (TONALITE)	DIORITE	GABBRO GABBRO—with clinopyroxene NORITE—with orthopyroxene OLIVINE GABBRO—with olivine TROCTOLITE—olivine and plagioclase only ANORTHOSITE—plagioclase only QUARTZ GABBRO—with quartz		THERALITE ESSEXITE NEPHELINE GABBRO TESCHENITE—analcite only feldspathoid OLIVINE THERALITE—with olivine	PERIDOTITE PERIDOTITE—clin… and olivine HARZBURGITE—… and olivine PICRITE—pyroxene… with some plagio… DUNITE—olivine… PYROXENITE—pyr… SERPENTINE (SERP… chiefly serpentine
SYENITE PORPHYRY	NEPHELINE SYENITE PORPHYRY	QUARTZ MONZONITE PORPHYRY	MONZONITE PORPHYRY	NEPHELINE MONZONITE PORPHYRY	GRANODIORITE PORPHYRY	QUARTZ DIORITE PORPHYRY	DIORITE PORPHYRY	GABBRO PORPHYRY	DIABASE (Dolerite of British) Phaneritic diabasic texture, normally medium or fine-grained	THERALITE PORPHYRY	PERIDOTITE PORPHYRY KIMBERLITE—porphyry or…
TRACHYTE PORPHYRY	PHONOLITE PORPHYRY	QUARTZ LATITE PORPHYRY	LATITE PORPHYRY	NEPHELINE LATITE PORPHYRY	DACITE PORPHYRY		ANDESITE PORPHYRY	BASALT PORPHYRY		TEPHRITE PORPHYRY	LIMBURGITE POR…
TRACHYTE	PHONOLITE LEUCITE PHONOLITE (Leucite trachyte)—leucite only feldspathoid TINGUAITE—abundant aegirine WYOMINGITE—leucite and phlogopite	QUARTZ LATITE (DELLENITE)	LATITE (TRACHY-ANDESITE)	NEPHELINE LATITE	DACITE		ANDESITE	BASALT OLIVINE BASALT—with olivine ANALCITE BASALT—with analcite QUARTZ BASALT—with quartz OCEANITE—with abundant olivine		TEPHRITE LEUCITE TEPHRITE—leucite only feldspathoid BASANITE—with olivine LEUCITE BASANITE—with olivine and leucite	LIMBURGIT…

Normally it is not possible to determine the composition of these rocks. They are customarily designated by the names at the left of this column. Basic glass is rare so rocks named, except scoria, will normally be silicic. If the approximate composition (by close association) or silica content (by refractive index or analysis), can be determined, the name may be prefixed by the name of the appropriate aphanitic rock, for example, "trachyte obsidian," or "latite vitrophyre." In general, scoria is basic; basic obsidian is called "tachylite"; and spherulitic tachylite is "variolite."

…ht colored
…ark colored

FREQUENCY OF OCCURRENCE:
This size type indicates COMMON ROCKS.
This size type indicates UNCOMMON ROCKS.
This size type indicates RARE ROCKS.

CLASTIC HOUS	CRYSTALLINE, CLASTIC, BIOCLASTIC, OOLITIC, ETC.		CLASTIC UNCONSOLIDATED - silt, sand CONSOLIDATED - siltstone, sandstone SIZE GRADES (mm.) 1/256 - 1/16, silt; 1/16 - 1/8 very fine sand; 1/8 - 1/4, fine sand; 1/4 - 1/2, medium sand; 1/2 - 1, coarse sand; 1-2, very coarse sand					
Clay Minerals or Clay-Size Material	Composition as Indicated in left column (prefix appropriate names for mixtures)	Chiefly Calcite or Dolomite	Chiefly Quartz			Quartz and >25% Feldspar	Quartz, Feldspar, Rock Chips, Pelitic Matrix, Angular grains, Tough.	Volcanic Ejecta
			>90% Quartz	Feldspar 10-25%	Rock Chips >10%			
		LIMESTONE DOLOMITE ETC. All varieties in the Calcite-Dolomite horizontal column are possible here.	QUARTZ SANDSTONE (Quartzose sandstone)	FELDSPATHIC SANDSTONE	LITHIC SANDSTONE	ARKOSE (Arkosic sandstone) Normally pink, red or light gray	GRAYWACKE—normally greenish gray SUBGRAYWACKE—low in feldspar, rock chips, or less angular grains. Tendency to chemical cement	ASH—unconsolidated fragments under 4 mm TUFF—consolidated ash VOLCANIC BRECCIA—angular fragments over 4 mm AGGLOMERATE—large proportion (>25%) of bombs
...ucture Includes claystone include much silt ...chiefly clay ...quently recrystallized ...gales in water		ARGILLACEOUS LIMESTONE ETC. All varieties in the Calcite-Dolomite horizontal column are possible here.	ARGILLACEOUS QUARTZ SANDSTONE	ARGILLACEOUS FELDSPATHIC SANDSTONE LOESS—fine sand or silt. Massive, porous, coherent	ARGILLACEOUS LITHIC SANDSTONE	ARGILLACEOUS ARKOSE	ARGILLACEOUS GRAYWACKE ARGILLACEOUS SUBGRAYWACKE	These rocks are classified on the proportions of vitric, crystal (mineral), or lithic material they contain, for example: "vitric lithic ash," or "crystal vitric tuff." If the mineralogy of the crystal or lithic fragments can be determined, the name of the appropriate volcanic rock can be prefixed as, "rhyolite vitric crystal tuff," or simply, "rhyolite tuff."
SILICEOUS SHALE " CLAYSTONE " MUDSTONE ETC.	SILICEOUS OOLITE—>50% oolitic OOLITIC CHERT—<50% oolitic DIATOMITE—diatom tests RADIOLARITE—radiolarian tests	SILICEOUS LIMESTONE—disseminated silica CHERTY LIMESTONE—containing chert nodules ETC. All varieties in the Calcite-Dolomite horizontal column are possible here.	ORTHOQUARTZITE (Sedimentary quartzite) (Siliceous quartz sandstone)	FELDSPATHIC ORTHOQUARTZITE (Siliceous feldspathic sandstone)	LITHIC ORTHOQUARTZITE (Siliceous lithic sandstone)	SILICEOUS ARKOSE (Quartzose arkose)	SILICEOUS SUBGRAYWACKE	
CALCAREOUS SHALE (Limy shale) etc MARLSTONE 25-75% carbonate	LIMESTONE—chiefly calcite, crystalline DOLOMITE (Dolostone)—chiefly dolomite, crystalline CLASTIC LIMESTONE (Calcarenite or calcite sandstone)—clastic CALCAREOUS OOLITE—>50% oolitic OOLITIC LIMESTONE—<50% oolitic COQUINA—shells, little cement ORGANIC LIMESTONE—highly fossiliferous		CALCAREOUS QUARTZ SANDSTONE	CALCAREOUS FELDSPATHIC SANDSTONE	CALCAREOUS LITHIC SANDSTONE	CALCAREOUS ARKOSE	CALCAREOUS SUBGRAYWACKE	
LIMONITIC or HEMATITIC (Ferruginous) SHALE ETC.	HEMATITE OOLITE—>50% oolitic LIMONITE OOLITE—>50% oolitic OOLITIC IRON ORE—<50% oolitic SIDERITE then carbonate—chiefly siderite, crystalline	LIMONITIC or HEMATITIC (Ferruginous) LIMESTONE ETC. All varieties in the Calcite-Dolomite horizontal column are possible here.	LIMONITIC or HEMATITIC (Ferruginous) QUARTZ SANDSTONE	LIMONITIC or HEMATITIC (Ferruginous) FELDSPATHIC SANDSTONE	LIMONITIC or HEMATITIC (Ferruginous) LITHIC SANDSTONE	LIMONITIC or HEMATITIC (Ferruginous) ARKOSE	LIMONITIC or HEMATITIC (Ferruginous) GRAYWACKE LIMONITIC or HEMATITIC (Ferruginous) SUBGRAYWACKE	
...RBONACEOUS ...ALE, ETC.—...arbonized ...mains. ...UMINOUS ...ALE (Oil shale) ...TC.—sapropelic	PEAT—dark semi-carbonized plant remains LIGNITE—brown-black well-carbonized plant remains	CARBONACEOUS LIMESTONE BITUMINOUS LIMESTONE ETC. All varieties in the Calcite-Dolomite horizontal column are possible here.	CARBONACEOUS QUARTZ SANDSTONE BITUMINOUS QUARTZ SANDSTONE	CARBONACEOUS FELDSPATHIC SANDSTONE BITUMINOUS FELSPATHIC SANDSTONE	CARBONACEOUS LITHIC SANDSTONE BITUMINOUS LITHIC SANDSTONE	CARBONACEOUS ARKOSE BITUMINOUS ARKOSE	CARBONACEOUS GRAYWACKE ETC. CARBONACEOUS SUBGRAYWACKE ETC.	
PHOSPHATIC SHALE, ETC.	PHOSPHATIC OOLITE—>50% oolitic ROCK SALT—crystalline ROCK ANHYDRITE—crystalline ROCK GYPSUM—crystalline GYPSUM SAND—clastic	PHOSPHATIC LIMESTONE ETC. All varieties in the Calcite-Dolomite horizontal column are possible here	PHOSPHATIC QUARTZ SANDSTONE ETC.	PHOSPHATIC FELDSPATHIC SANDSTONE ETC.	PHOSPHATIC LITHIC SANDSTONE ETC.	PHOSPHATIC ARKOSE ETC.	PHOSPHATIC SUBGRAYWACKE ETC.	

...s and should be pre-
...t feature of the rock
...ze (sandstones only),
...structure includes, for
...edded," "thinly lam-

nated," etc. The size grade for conglomerates should immediately precede "conglomerate." Some common nonmineral minor constituent terms are "tuffaceous," "cherty," "fossiliferous," "crinoidal," "coralline," "clayey (argillaceous)," "silty," "shaly," "sandy (arenaceous)," and "conglomeratic." Minor mineralogy should follow the

monomineral composition and should be restricted to one conspicuous mineral not implied in the rock name. It should be applied in adjective form as "micaceous," "chloritic," "glauconitic," and "pyritic." The most common cement terms are given in the chart with the root names. Some typical rock names are "black thin-bedded

micaceous shale," "gray massive, medium-grained glauconitic quartz sandstone," "tan siliceous quartz pebble conglomerate," and "white vuggy foraminiferal limestone."

Graywacke currently has two meanings. To some it denotes a feldspar quartz sandstone with more than 20 (or 15) percent pelitic matrix. To many others, it has retained its original meaning, that is a very hard, firm sandstone without porosity or chemical cement. In addition, these "true" graywackes typically have extremely angular grains, a pelitic matrix, and a dark color.

	CHARACTERIZING ACCESSORY MINERALS	NONDIRECTIONAL STRUCTURE Massive or Granulose		DIRECTIONAL STRUCTURE (Lineate or Foliate)			
		Contact Metamorphism*		Mechanical Metamorphism	Regional Metamorphism		
		Fine Grained (Aphanitic)	Medium or Coarse Grained (Phaneritic)	Cataclastic	Slaty	Phyllitic	Schistose
		METAQUARTZITE MARBLE BRUCITE MARBLE SOAPSTONE—chiefly talc HORNFELS—any metamorphic rock with nondirectional structure	METAQUARTZITE MARBLE BRUCITE MARBLE TREMOLITE MARBLE WOLLASTONITE MARBLE TREMOLITE HORNFELS WOLLASTONITE HORNFELS CALC-SILICATE HORNFELS—chiefly calc-silicate minerals	These rocks are formed by crushing and shearing with only minor recrystallization. If there are no conspicuous directional features, the rock is called "crush breccia" if coarse grained, and "cataclasite" if fine grained. Most of them, however, are foliate. MYLONITE—finely ground, foliate FLASER GRANITE, FLASER DIORITE, FLASER CONGLOMERATE, ETC.—flaser structure AUGEN GNEISS—augen structure ULTRAMYLONITE—partially fused mylonite Rocks with only minor deformation may be called "schistose," for example "schistose sandstone," "schistose rhyolite," etc., but these are not properly metamorphic rocks.	Most slates are dark colored	PHYLLITE is intermediate between slate and schist. It differs from slate in that crystallization of micaceous minerals imparts a sheen to the rock; it differs from schist in that grains are too small for megascopic identification. PHYLLONITE—a phyllite owing its fine grain to mylonitization	QUARTZ-MICA SCHIST TALC SCHIST SILLIMANITE SCHIST ALBITE-MICA SCHIST QUARTZ-SERICITE SCHIST KYANITE SCHIST CALCITE SCHIST (Schistose marble)
ONS S	Muscovite Sericite Sillimanite Kyanite Cordierite Tremolite Wollastonite Albite Andalusite Garnet Phlogopite Diopside Enstatite Staurolite Glaucophane Anthophyllite Pyrophyllite Chloritoid Actinolite Tourmaline Epidote Chiastolite Olivine Serpentine Chlorite Biotite Graphite Chondrodite Scapolite	METAQUARTZITE MARBLE SKARN—pyroxene-garnet-carbonate hornfels SOAPSTONE—chiefly talc HORNFELS—any metamorphic rock with nondirectional structure SERPENTINE*	METAQUARTZITE MARBLE DIOPSIDE MARBLE CHONDRODITE MARBLE ANDALUSITE HORNFELS SKARN—pyroxene-garnet-carbonate hornfels GARNET HORNFELS KYANITE HORNFELS ANTHOPHYLLITE HORNFELS CALC-SILICATE HORNFELS SERPENTINE* CORDIERITE-ANTHOPHYLLITE HORNFELS				MICA SCHIST CHIASTOLITE SCHIST ANDALUSITE SCHIST STAUROLITE SCHIST KYANITE SCHIST PYROPHYLLITE SCHIST GARNET-MICA SCHIST SERPENTINE* TOURMALINE-MICA SCHIST ANTHOPHYLLITE SCHIST STAUROLITE-KYANITE SCHIST SILLIMANITE-GARNET SCHIST GRAPHITE SCHIST CALCITE SCHIST (Schistose marble) SCHISTOSE QUARTZITE
		METAQUARTZITE MARBLE SKARN—pyroxene-garnet-carbonate hornfels GRAPHITE MARBLE CHLORITE MARBLE SERPENTINE MARBLE (Ophicalcite) HORNFELS—any metamorphic rock with nondirectional structure SERPENTINE*	METAQUARTZITE MARBLE GRAPHITE MARBLE CHLORITE MARBLE OLIVINE MARBLE SKARN—pyroxene-garnet-carbonate hornfels ACTINOLITE MARBLE ACTINOLITE-EPIDOTE HORNFELS ACTINOLITE HORNFELS PYROXENE HORNFELS EPIDOTE HORNFELS TOURMALINE HORNFELS ANDALUSITE-BIOTITE HORNFELS SERPENTINE* ECLOGITE—pyroxene-garnet hornfels MAGNETITE ROCK CORDIERITE HORNFELS AMPHIBOLITE—chiefly hornblende and/or plagioclase		SILTY SLATE GREEN SLATE BLACK SLATE SPOTTED SLATE ANDALUSITE SPOTTED SLATE CHIASTOLITE SPOTTED SLATE BIOTITE SPOTTED SLATE CARBONACEOUS SLATE CALCAREOUS SLATE		GREENSCHIST CHLORITE SCHIST CHLORITOID SCHIST GLAUCOPHANE SCHIST AMPHIBOLITE (HORNBLENDE SCHIST) ACTINOLITE SCHIST GRAPHITE SCHIST PYROXENE SCHIST EPIDOTE-CHLORITE SCHIST HORNBLENDE-BIOTITE SCHIST BIOTITE-CHLORITE SCHIST SERPENTINE* TOURMALINE SCHIST EPIDOTE AMPHIBOLITE GARNET-PYROXENE AMPHIBOLITE GARNET-CHLORITE SCHIST

…c rock consists chiefly of pre-
…ucriate rock name. The rock
…the new mineral composition
"metatuff," etc., is applied to
…ut have largely retained their
…are genetically important and
…of their quantity

*SERPENTINE is a product of hydrothermal alteration which some authorities consider to be an igneous process and others a metamorphic process. For this reason, serpentine appears both on this chart and on the igneous rock chart.

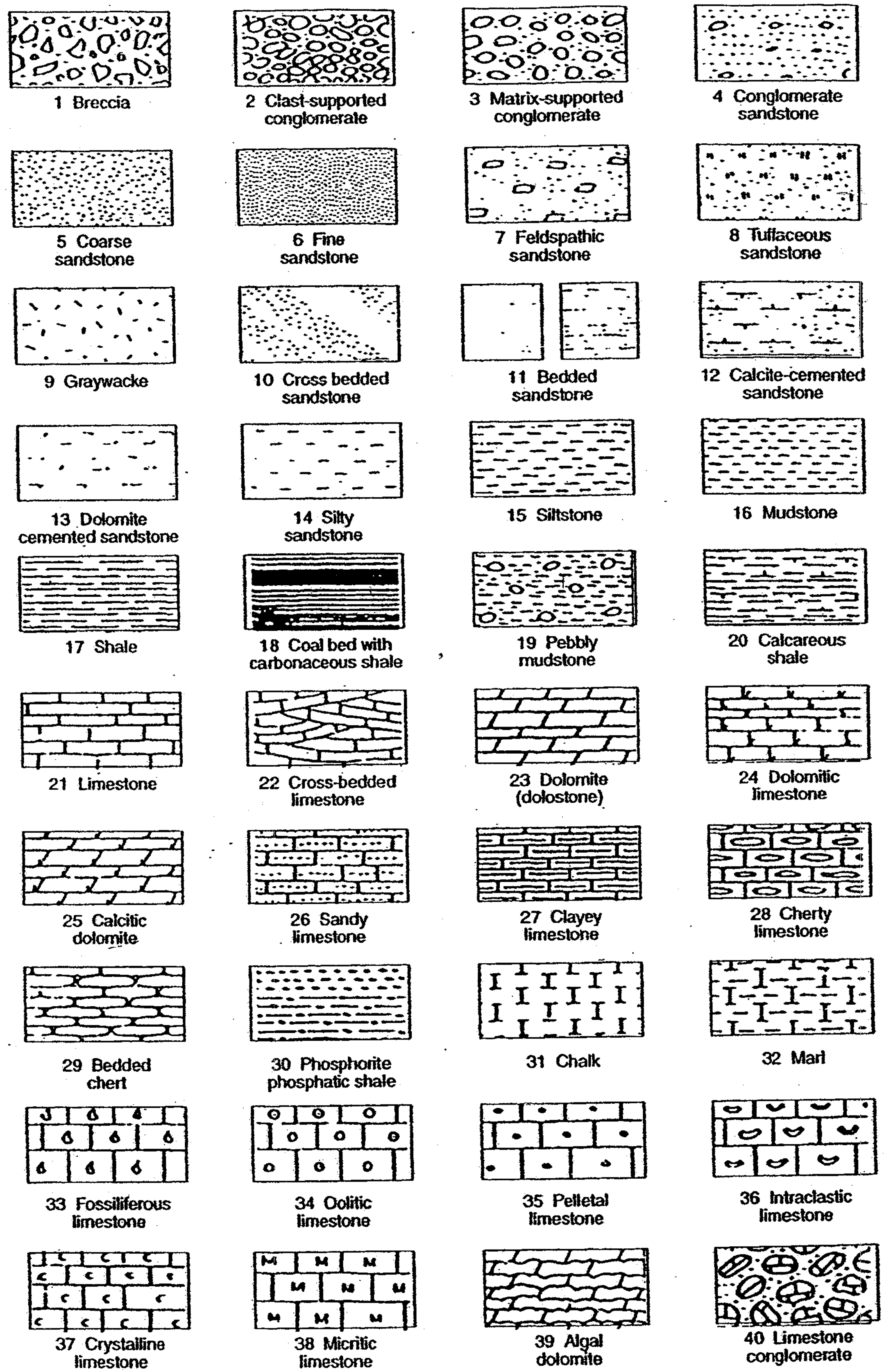


FIGURE **8a**

LITHOLOGIC SYMBOLS

TP-1.2-2

from Compton 1985

PROJECT NO. IP3 1024 DRAWING NO. 61349 DATE 5/2/96 DRAWN BY CB

Golder Associates

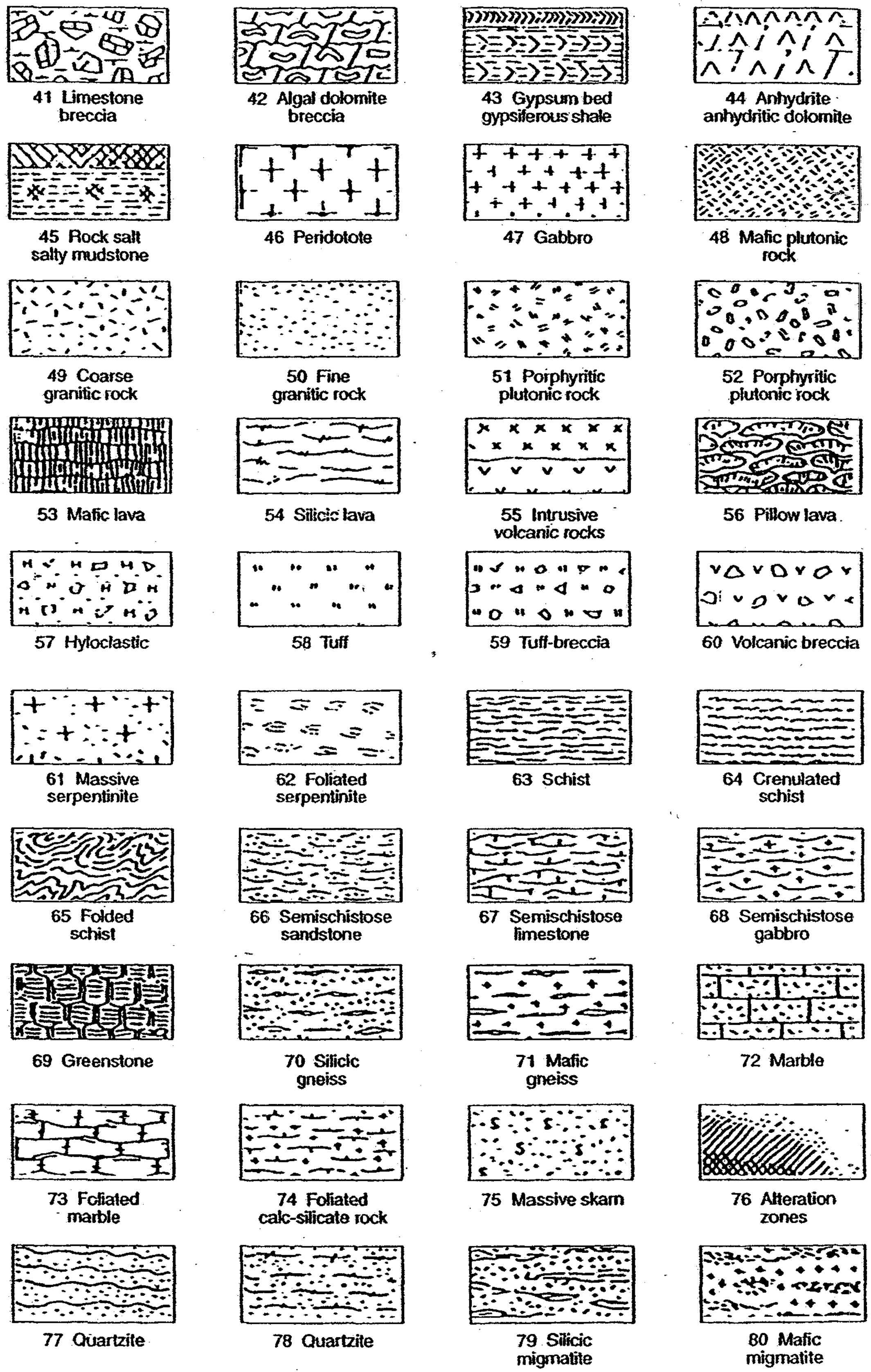


FIGURE **8b**

LITHOLOGIC SYMBOLS

TP-1.2-2

from Compton 1985

PROJECT NO. IP3 1024 DRAWING NO. 61350 DATE 5/2/96 DRAWN BY CB

Golder Associates

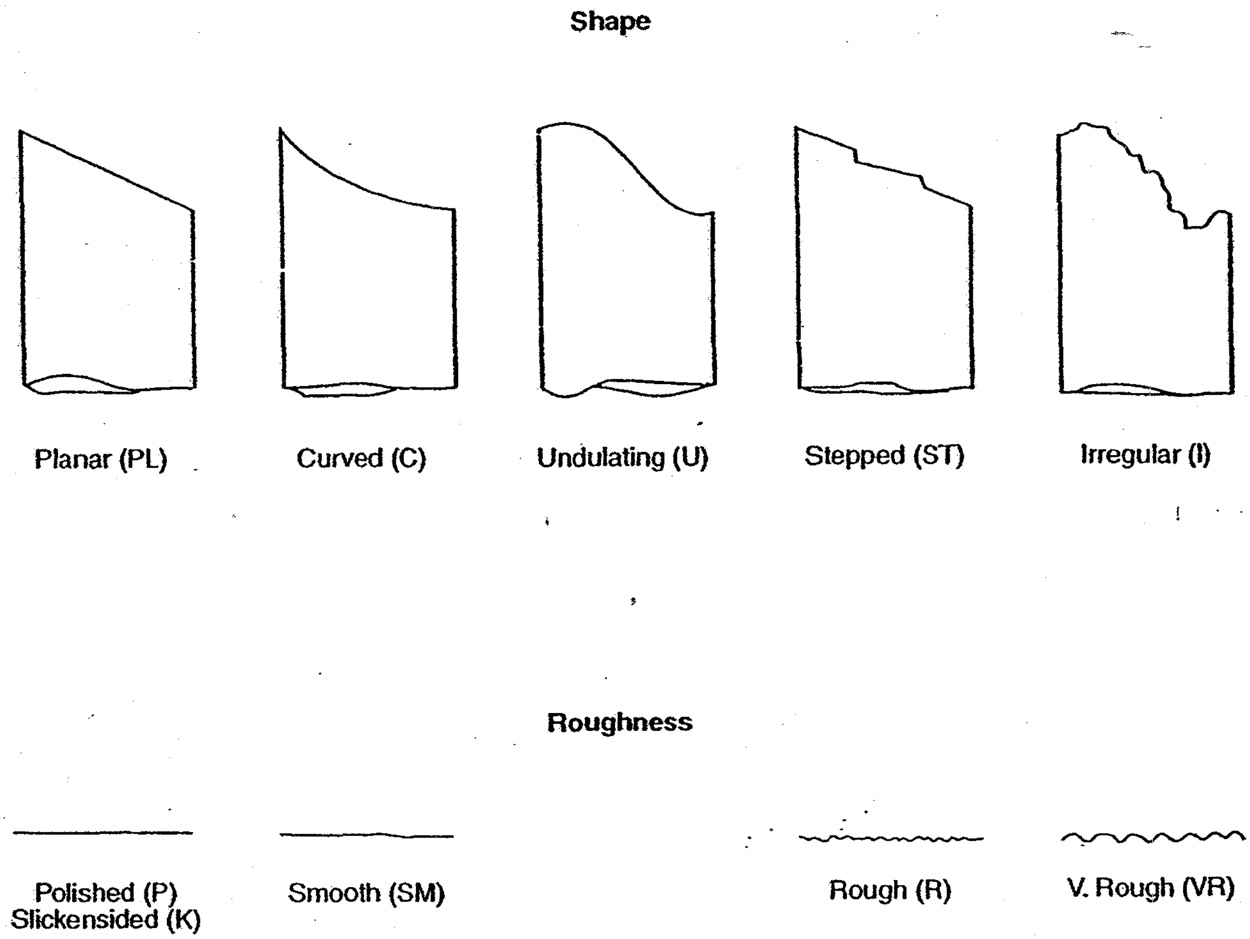
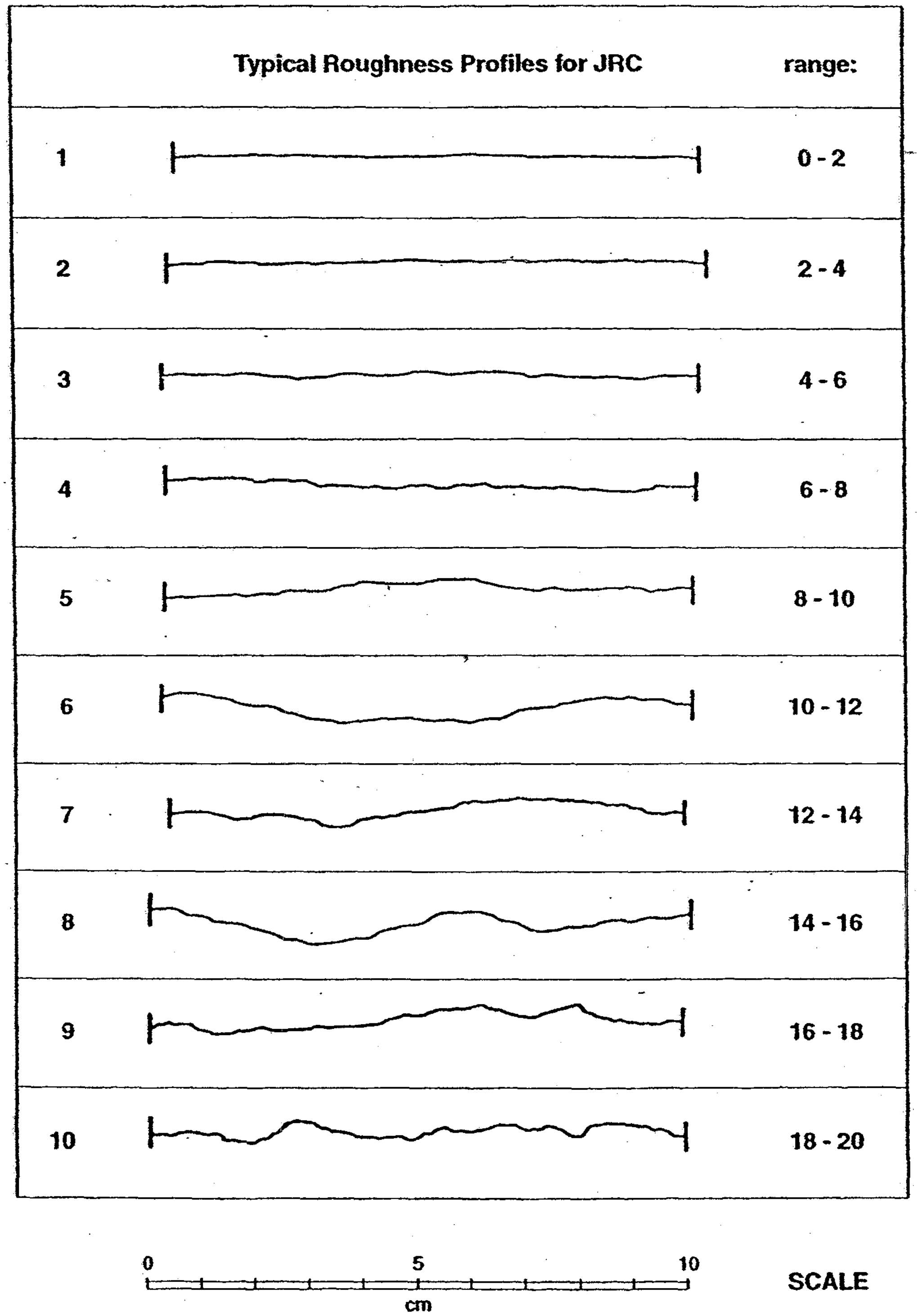


FIGURE 9
PHYSICAL DESCRIPTIVE TERMS
TP-1.2-2

PROJECT NO. IP3 1024 DRAWING NO. 61348 DATE 5/2/96 DRAWN BY CB

Golder Associates

Suggested Methods for the Quantitative Description of Discontinuities



from Brown 1981

FIGURE 10
DISCONTINUITY ROUGHNESS PROFILE
TP-1.2-2

PROJECT NO. IP3 1024 DRAWING NO. 61351 DATE 5/2/96 DRAWN BY CB

Golder Associates

RECORD OF DRILLHOLE

Sheet of

PROJECT
PROJECT NO:
LOCATION:

BORING METHOD:
DRILLING DATE:
DRILL RIG:

DATUM:
COORDINATES N:
AZIMUTH:

COLLAR ELEV:
E:
INCLINATION:

J-Joint, F-Fault, S-Shear, B-Bedding, FO-Foliation, PL-Planar, C-Curved, U-Undulating, ST-Stepped, I-Irregular, P-Polished, K-Slickensided, SM-Smooth, R-Rough, VR-V.Rough, Fr-Fracture, Fe-Iron Oxides, CA-Calcite, CL- Clay

DEPTH SCALE (FEET)	ROCK TYPE DESCRIPTION	GRAPHIC LOG	ELEV DEPTH (FT)	RUN NO.	CORE RECOVERY	RQD 80 60 40 20	FRACTURES PER FOOT 2 4 6 8 10	DISCONTINUITY DATA: 0 30 DIP w.r.t. CORE AXIS 60 90	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	DISCONTINUITY DATA: GRAPHIC LOG	HYDRAULIC CONDUCTIVITY k (cm/s)	NOTES WATER LEVELS INSTRUMENTATION

SCALE:
DRILLING CONTRACTOR:
DRILLER:

LOGGED:
CHECKED:
DATE:

Golder Associates

FIGURE **11**
EXAMPLE OF ALTERNATIVE FORMAT
TP-1.2-2

924/66692/7-1-96

SUMMARY GEOTECHNICAL LOG

PAGE ______ OF ______

ROJECT: ____________________

ROJECT NO.: ____________________

OGGED BY: ____________________

ATE: ____________________

DRILL HOLE: ____________________

CORE SIZE: ____________________

DRILL RIG: ____________________

AZIMUTH: ____________________

INCLINATION: ____________________

LOCATION: N ____________________

E ____________________

Depth (ft)	Length (ft)	Geologic Unit	Core Recovery		RQD (sound core > 4 in. per depth interval)		Fracture Index		Alteration Index		Strength Index	Discontinuity Data (type, surface, orientation)	Comments
			ft.	%	ft.	%	No. of Frac.	Frac. per ft.	1	2			
om ______ ______													
om ______ ______													
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FIGURE 12

TP-1.2-2

Golder Associates

FIELD CHANGE REQUEST

Golder Associates

Job/Task Number: ______________________________

Other Affected Documents: ______________________________

Requested Change: ______________________________

Reason for Change: ______________________________

Change Requested by: ______________________________ Date ______________

Reviewed by: ______________________________ Date ______________
GAI Project Manager

Comments: ______________________________

Reviewed by: ______________________________ Date ______________
GAI QA Manager

Comments: ______________________________

FIGURE 13
FIELD CHANGE
REQUEST FORM
TP-1.2-2

TP-1.2-6
Revision Level -7-
RECORD OF REVISIONS

<u>Section</u>	<u>Description of Revisions</u>
All	New format throughout
4.	Updated ASTM standard
5.	Changed "foundation" engineering to "geotechnical" engineering
7. & Table 1	Changed one-half-inch (12 mm) rebar to 1/4-inch steel hand probe
8.1	Added more detail to soil descriptions
Figure 2	Updated Record of Borehole log to reflect current form

1. PURPOSE

This technical procedure describes uniform procedures for identification of soils.

2. APPLICABILITY

This technical procedure is applicable to all persons engaged in soils identification.

3. DEFINITIONS

Definitions are contained within Section 8.

4. REFERENCES

ASTM Standards, Standard Recommended Practice for Description of Soils (Visual-Manual Procedure), D 2488-93, American Society for Testing and Materials, Philadelphia, Pennsylvania.

Rock-Color Chart, Geological Society of America, Boulder, Colorado.

5. DISCUSSION

Soil identification techniques are employed to characterize and describe soil for geologic and hydrologic interpretation, geotechnical engineering, well screen sizing, and a wide range of other purposes.

6. RESPONSIBILITY

Each individual designated responsibilities for soil identification shall utilize this procedure.

7. EQUIPMENT AND MATERIALS

Supplies required for Golder Associates field personnel generally include the following:

- Supply of water
- Pocket knife or small spatula
- Small test tube with stopper or glass jar with sealed lid
- Small hand lens
- Pocket penetrometer or shear gage
- 1/4" steel hand probe
- Notebook
- Exploration logs

8. PROCEDURE

8.1 General

The recommended Soils Classification System is based on the Unified Soil Classification System as summarized on Figure 1.

The soil description involves the following general format:

(1) Consistency or Density,
(2) Color,
(3) Structural Characteristics,
(4) Composition with Major Component in Capital Letters,
(5) Minor Characteristics,
(6) Uses Classification in Capital Letters,
(7) Geologic Description in Capital Letters.

Thus, for example, a typical description might include:

Stiff, Light Grey (N7), stratified, SILTY CLAY, trace Sand, slickensides, (CL) (LACUSTRINE)

The following sections discuss the different elements (1-7 above) of the soil description.

8.2 Determination of Consistency or Relative Density

8.2.1 N-Values

The standard penetration test (SPT), or number of blows required by a 140-pound hammer or weight dropped 30 inches to drive a two-inch O.D. (1 3/8-inch ID) drive-open sampler, will indicate the relative density of cohesionless soils and the consistency of cohesive soils. The standard tests penetrates 18 inches. N values are the blows required to drive the sampler the last 12 inches. The blows required to drive the sampler the first six inches are normally not taken into account unless one or both of the subsequent blow counts are affected by gravel of cobbles. Blows are recorded for each six-inch interval. The relative density or coarse-grained soils is shown in Table 1.

8.2.1.1 Relative Density of Granular Soils

The relative density modifiers given in Table 1 for coarse-grained soils should also be used for fine-grained non-plastic soils described predominately by SILT.

8.2.1.2 Consistency of Fine-Grained, Cohesive Soils

Shown in Table 2 are criteria for the quantitative and qualitative determination of the consistency of fine-grained, cohesive soils. The criterion based on N-Values is considered unreliable and should be used with caution. The criterion based on undrained shear strength may be used when values of undrained shear strength are available. The field identification test is simple and reliable and is the method which can be used in most instances.

8.3 Determination of Color

Color can be an important property in identifying materials of similar geologic origin and in identifying organic soils. Although qualitative color names are somewhat helpful, positive color identifications obtained by comparison with a standard color chart are even more useful. If the sample contains layers or patches of varying colors, this should be noted and all representative colors should be described for moist samples. If possible, color should be described for moist samples. The Geologic Society of America Rock-Color Chart should be used to identify color. Provide both the color name and chromal hue symbols in soil descriptions. Mottled soils show the presence of spots, streaks, or splotches of one or more colors in a soil mass of another predominant color. In mottled soils, the colors are not mixed and blended, but each is more or less distinct in the general ground color.

8.4 Definitions of Structural Characteristics

8.4.1 Stratified

Composed of, or arranged in, layers. The layers are parallel to one another, and composed of soils visibly different from each other.

8.4.2 Parting

Paper-thin separation of one soil type within another. Usually applied to cohesive soils.

8.4.3 Rhythmic

Consisting of alternative thin layers of sand, silt or clay. Each layer generally less than one-half-inch in thickness. Lacustrine deposits with annual layers are termed varves or are said to be varned.

8.4.4 Lenses

A particular soil type significantly different from the surrounding soils which thins out laterally is said be a lens or be lens-shaped.

8.4.5 Pocket

A different soil type of limited thickness and lateral extent.

8.4.6 Homogenous

Of uniform structure.

8.4.7 Heterogeneous

Consisting of dissimilar constituents, mixed.

8.4.8 Slickensided/Polished/Scratched Surfaces

A polished and scratched surface that results from friction of one block of material moving relative to another block. Polished and/or scratched surfaces may be related to minor movement along discontinuities or may be related to faults and termed slickensides.

8.4.9 Fissured

This term applies to hard, over-consolidated silts and clays and refers to physical discontinuities such as fissures and cracks that formed during or after consolidation. The abundance and character of the fissuring can be described as follows:

"Highly Fissured" - Fractures are spaced one-half-inch or closer over most of the interval described.

"Moderately Fissured" - Sample contains two or more fractures or thin fracture zones per six-inch sample, but average spacing is wider than one-half inch.

"Locally Fissured" - Only one fracture or narrow (less than three inches) fracture zone is observed in a sample.

Fissuring characteristics that can be noted and/or described include attitude, length, width, aperture (closed, tight, open), staining/infilling, roughness, curvature, continuity, slickensides, polish, gouge, relation to other structures and other distinguishing features.

8.5 Determination of Soil Composition

8.5.1 General

For purposes of soil description, the material is considered to be composed of the coarse fraction or of particles larger than the No. 200 sieve (+.074 mm) and the fine fraction or those smaller than the No. 200 sieve. The coarse fraction is described based on its particle size while the fines are described on its plasticity.

The following terminology is used to denote the percentage by dry weight of each soil component:

Descriptive Term	Range of Proportion
Trace	0-5%
Little	5-12%
Some or Adjective*	12-30%
And	30-50%

*Adjective: silty, sandy, gravelly, etc.

For example: "SILT, some Sand, trace Gravel" describes a basic soil component of silt (30-50 percent), with minor components of sand (12-30 percent), and gravel (0-5%).

Soils are to be described according to the following criteria with the principal constituents written in capital letters. Other constituents are preceded by descriptive terminology that is used to denote the percentage by weight of each component. Soil descriptions are determined visually except where laboratory classification test data are available. The following abbreviations are acceptable:

c = coarse
m = medium
f = fine

8.5.2 Field Indication Tests - Fines

8.5.2.1 Fine-Grained Soil Descriptions

The description of fine-grained soil components (i.e., passing the No. 200 sieve or smaller than 0.074 mm) is based on plasticity and not grain size. Thus, terms like SILT, trace Clay or Silt, little Clay are not used. Rather, the terms, SILT, CLAYEY SILT, SILTY CLAY, and CLAY are applied to the fine-grained component as a whole. Their characteristics are described in Table 4.

8.5.2.2 Field Test for Plasticity

Plasticity refers to the ability of a material to be deformed rapidly without cracking or crumbling and then maintain that deformed shape after the deforming force has been released. A soil is said to be highly plastic if there is a wide range of moisture content over which it remains in the plastic state. High plasticity indicates a high clay content. Identification of cohesive soils in relation to their plasticity can be made on the following basis: The natural soil is worked until its moisture content is such that a 1.5-inch diameter ball formed from the soil shows a flattened contact surface of 7/8-inch diameter when dropped from a height of two feet (gravel sizes are not included in the ball). The smallest thread possible without crumbling is then rolled from the above soil sample. The approximate relationships below are then used for identification:

Thread Diameter	Descriptive Term
1/4-inch	SILT
1/8- to 1/16-inch	CLAYEY SILT
1/32-inch	SILTY CLAY
1/64-inch	CLAY

8.5.2.3 Dry Strength

A portion of the soil is allowed to dry out completely in air. An angular fragment (about one-half-inch) of the dried soil is pressed between the fingers. The dry strength of the fragment is expressed as very low, low, medium, high and very high. Fragments with very high strength cannot be injured at all, whereas, those of very low strength disintegrate completely on gentle pressure. The strength is called medium if the fragment can be reduced to powder only with great effort. Those materials with greater dry strengths are predominately clayey, and those with less dry strength are predominately silty.

8.5.2.4 Stickiness

A high degree of stickiness in the natural state is indicative of higher plasticity.

8.5.2.5 Shine Test

If a moist lump of soil is stroked with considerable pressure with the flat of a pen knife blade or fingernail, the type of surface imparted is an indication of the soil. If a shiny surface results, the presence of clay is indicated. Silt is indicated if a dull surface is produced.

8.5.2.6 Grittiness Test

THIS TEST SHOULD NOT BE PERFORMED WHEN HAZARDOUS WASTE CONTAMINATION IS SUSPECTED OR KNOWN TO BE PRESENT. In other cases, when a small amount of the uncontaminated soil is placed between the teeth, the presence of grit will indicate silt or sand, but if no grit is detected, a pure clay is present.

8.5.3 Field Identification Tests - Organic Soils

8.5.3.1 Organic Soil

Description of organic soils depends on the percentage and distribution or organics in the soil. If the soil matrix is inorganic with occasional pieces or organic matter, this can be described under Minor Characteristics.

If the soil is primarily inorganic, but contains a significant amount of organic, the modifier organic can be used. If the soil is primarily organic, then it should be called a Peat. Examples include:

- Silty SAND, occasional organic matter
- Organic SILT
- Sandy PEAT

Table 5 includes a system for classifying organic soils.

8.5.3.2 Organic Cohesive Soils

Organic cohesive soils display the following characteristics.

- A dark-brown, dark-gray, black color indicates the presence of organic matter.
- An odor of decaying vegetation is typical. If organic matter cannot be distinguished, it can sometimes be brought out by a small amount of heat.
- The presence of fibrous or root structures, twigs, leaves or shells is common.
- At least a three-quarter reduction in the liquid limit value after oven-drying is considered positive identification of organic soil.
- The plasticity of fine-grained organic soils is greatly reduced on oven-drying due to irreversible changes in organic colloids.
- Organic clays feel spongy in the plastic range as compared to inorganic clays.

8.5.3.3 Organic Soil - Peat

Peat is usually dark brown to black; contains fibrous particles of vegetation in varying states of decay; has characteristic organic odor; is usually spongy and compressible; commonly contains natural moisture contents of over 100 percent and can contain organic and inorganic silts and clays in varying amounts and concentrations.

8.5.4 Field Identification Tests - Cohesionless Soils

8.5.4.1 Visual Identification of Grain Size

The constituent parts of a soil sample are defined by grain size, as indicated in Table 3.

8.5.4.2 Grittiness Test

THIS TEST SHALL NOT BE PERFORMED WHEN HAZARDOUS WASTE CONTAMINATION OF THE SOIL IS SUSPECTED OR KNOWN TO BE PRESENT.

The soil is handled lightly between the thumb and forefinger to get an idea of the grittiness or softness of the soil. A pinch of uncontaminated soil is smeared with considerable pressure between the thumb and forefinger to determine the degree of harshness and grittiness. When a small amount of uncontaminated soil is placed between the teeth, the presence of grit will indicate silt or sand, but if no grit is detected, an almost pure clay is present.

- Coarse to medium sand exhibits a typically harsh and very gritty smear.
- Coarse to fine sand has a less harsh feel, but exhibits a very gritty smear.
- Medium to fine sand exhibits a less gritty feel and smear.
- Fine sand has a softer feel and much less gritty smear.

8.5.4.3 Test Tube Test

A small sample of the soil (lumps are first broken up) is shaken in a test tube or glass jar filled with water and is allowed to settle. All the fine sand will settle out (four-inch fall) in 30 seconds; the silt in 50 minutes. A rough idea of the grain sizes can be obtained by this test.

8.5.4.4 Dilatancy Test

When a wet pat of soil is shaken vigorously in the hand, the surface will become glassy and show free water. If the pat of soil is then squeezed in the fingers with free water disappearing and the surface becomes dull, the soil is NOT a clay soil, but a silt or fine sand. If the free water on the surface disappears immediately (as walking on the beach adjacent to the water), the soil is most likely a fine sand. If the free water tends to ooze away, the soil is most likely silt.

8.5.5 Determination of Soil Types

Based on the tests and observations described in the previous text, the soil description can be made by compiling the properties of the soil and comparing them to Table 2.

8.6 Minor and/or Usual Characteristics

8.6.1 General

Minor characteristics of the soil sample should be included in its description. These characteristics include occasional traces of organic debris, mention of other types of deleterious materials such as a trash or cinder fill, portions of cobbles or boulders received in the sampler, and pockets and/or lenses of material other than those already mentioned in the description. A minor constituent, such as gravel, which is part of the overall soil matrix, would be described using the modifiers presented in 8.5.1.2 (i.e., trace, little, etc.). In some cases, a minor constituent is scattered throughout the unit and is not part of the matrix. In this case, it would not be described as a minor characteristic. An example would be a lacustrine clay with ice rafted pebbles. Thus, the soil would be described as SILTY CLAY, scattered pebbles, and not SILTY CLAY, little gravel.

8.6.2 Determination of Moisture Content

Moisture descriptions should not generally be used and can be misleading. A general qualitative description can be applied if necessary. The following descriptions can be used:

- Dry: No discernible moisture present.
- Damp: Enough moisture present to darken the appearance, but no moisture on materials adheres to the hand.
- Moist: Will moisten the hand.
- Wet: Visible water present; plastic materials will leave sticky residue in hand when remolded.

As an example, hard clays often appear dry, but may be saturated even above the water table. However, in soft soils or granular soils, the moisture content can be relevant.

8.7 Unified Symbols

The Unified Soil Classification System symbols should be indicated on the final boring and test pit logs. These symbols are based on soil groupings as shown on Figure 1.

8.8 Definitions of General Geologic Descriptions

Generally, a geologic term, in capital letters, should be applied to major soil units, if appropriate. However, in many cases, there is inadequate information to determine a precise geologic description. In these cases, the term "possible" can be applied (i.e., possible TILL).

As appropriate, specific geologic names such as Lawton Clay can be used. However, when used, there should be sufficient specific geologic evidence of the name designation. If in doubt, do not use specific name or add "possible."

8.8.1 Fill

Material placed by humans.

8.8.2 Peat or Organic Matter

Natural deposit composed primarily of organic matter.

8.8.3 Lacustrine Deposits

Deposited in lakes.

8.8.4 Alluvial Soil

Any soil that has been deposited by a stream. Such soils usually contain some sand and rounded gravel or cobbles.

8.8.5 Till

A nonstratified random mixture of clay, silt, sand, gravel and boulders deposited by glaciers. Alternating layers of clayey till and till containing boulders are possible.

8.8.6 Outwash

A stratified alluvial soil transported and deposited by a glacial meltwater stream.

8.8.7 Loess

A uniform aeolian (wind) deposit of silty material having an open structure and relatively high cohesion due to a clay matrix or cementation by calcareous material at grain contacts. A characteristic of loess deposits is that they display nearly vertical slopes.

8.8.8 Pedogenic Soils

Soils that have formed in place due to decomposition of rock. Shales form residual clays. Limestones form lean brown and fat red clays. Granitic rocks form silty sand with angular sand grains.

8.8.9 Colluvial Soil

A nonstratified mixture of angular sand, gravel and boulder size material accumulated at the foot of a slope or on the slope itself chiefly under the influence of gravity.

8.9 Reaction To Dilute Hydrochloric Acid

Some soils show definite evidence of cementation in the intact state. Where this is noted, the degree of cementation may be described as weak or strong. Since calcium carbonate is the most common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important. The intensity of the HCl reaction should be described as none (NR), weak (WR), or strong (SR).

8.10 Report Format

The boring logs used in the report should conform to the general format shown on the attached example boring log, Figure 2. In addition to the logs, all reports should include the Classification System as shown in Tables 1 through 6. Some specific comments on the final boring log include:

- ACTUAL BLOW COUNTS: The actual blow count raw data shall be shown on the logs; i.e., blows per six inches.
- UNIFIED SYMBOL: A column will be used to show the Unified Symbol for the soil.
- PENETRATION/RECOVERY: The amount of sample penetration and recovery will be shown on the log.
- COLUMN FOR LAB TESTS: The locations of all lab tests (except for water contents and Atterberg limits which are shown graphically) should be indicated in shorthand as shown on the Sample Log and on Figure 1.

- SOIL CONTACTS: Under "Description" on Figure 2, horizontal solid and dashed lines are used to represent soil contacts. Solid lines represent soil contacts between major units; dashed lines represent gradation contacts within the same major unit. Inclined lines in the "USCS Class" column represent uncertainty of the depth of actual soil contact.

- TYPED: Logs shall be typed and not hand-lettered unless requested by the client.

- PLOTTING OF BLOW COUNTS AND MOISTURE CONTENTS: All logs shall include a disclaimer relating to these plots due to the liability associated with interpretations that could be applied to these graphs.

IP3-1024\TP126.RV7

TABLE 1

RELATIVE DENSITY OF COARSE-GRAINED SOILS

Relative Density	N, Blows/Foot*	Field Identification
Very Loose	0-4	Easily penetrated with shovel handle.
Loose	4-10	Easily penetrated with 1/4-inch steel probe pushed by hand. Easily excavated with hand shovel.
Compact	10-30	Penetrated 6" or less with 1/4-inch steel probe pushed by hand. Difficult to excavate with hand shovel.
Dense	30-50	Penetrated 2" or less with 1/4-inch steel probe pushed by hand. Must be loosened with pick to excavate.
Very Dense	>50	Cannot be penetrated with 1/4-inch steel probe pushed by hand.

*Judgment required if soils contain gravel and cobbles since the "N" value may be unreliable in determining relative density.

TABLE 2

CONSISTENCY OF COHESIVE SOILS

Consistency	N (blows/ft.) (unreliable)	Undrained Shear Strength* (psf)	Field Identification
Very soft	0-2	Less than 250	Extrudes from between fingers when squeezed in hand
Soft	2-4	250-500	Molded by light finger pressure
Firm	4-8	500-1,000	Molded by strong finger pressure
Stiff	8-15	1,000-2,000	Indented by thumb
Very Stiff	15-30	2,000-4,000	Indented by thumbnail
Hard	Greater than 30	Greater than 4,000	Difficult to indent with thumbnail

*Undrained shear strength equals one-half the unconfined compressive strength.

TABLE 3

COMPONENT DEFINITIONS BY GRADATION

Component	Size Range
Boulders Cobbles	Above 12 inches in diameter 3 to 12 inches
Gravel Coarse Gravel Fine Gravel	3 inches to No. 4 (4.76 mm) 3 inches to 3/4 inch 3/4 inches to No. 4 (4.76 mm)
Sand Coarse Sand Medium Sand Fine Sand	No. 4 (4.76 mm) to No. 200 (0.074 mm) No. 4 (4.76 mm) to No. 10 (2.0 mm) No. 10 (2.0 mm) to No. 40 (0.42 mm) No. 40 (0.42 mm) to No. 200 (0.074 mm)
Silt and Clay	Finer than No. 200 (0.074 mm)

COMPONENT PROPORTION

Descriptive Term	Range of Proportion
Trace Little Some or Adjective*	0-5% 5-12% 12-30%

*Adjective: silty, sandy, gravelly, etc.

For example: "SILT, some Sand, trace Gravel" describes a basic soil component of silt (30-50 percent), with minor components of sand (12-30 percent), and gravel (0-5%).

TABLE 4

FINE GRAIN DESCRIPTIONS

Descriptive Term	Plastic Index*	Characteristics
SILT	Less than 2	Rapid pronounced response to shaking test, very low cry strength; has almost a granular appearance and feel; thread cannot be rolled or can only be rolled with great difficulty.
CLAYEY SILT	2-15	Noticeable response to shaking and squeezing test, but appreciably less pronounced than for silt; low medium dry strength; slightly sticky, slightly slick and smooth smear; can roll a thread easily.
SILTY CLAY	15-40	No response to shaking and squeezing test; medium to high dry strength; rather sticky when moistened; moderately slick and smooth smear; can roll a thread when moderately dry.
CLAY	Greater than 40	No response to shaking test; high to very high dry strength; slick and waxy, can roll a thread when quite dry.

*Plastic Index: Liquid limit minus plastic limit.

DESCRIPTION BASED ON FIELD TEST FOR PLASTICITY

Thread Diameter	Descriptive Term
1/4-inch	SILT
1/8- to 1/16-inch	CLAYEY SILT
1/32-inch	SILTY CLAY
1/64-inch	CLAY

TABLE 5

SOIL CLASSIFICATION FOR ORGANIC SOILS

Category	Name	Organic Content (% by wt.)	Group Symbols (See Table 3)	Distinguishing Characteristics For Visual Identification	Range of Laboratory Test Values
ORGANIC MATTER	FIBROUS PEAT (woody, mats, etc.)	75 to 100% Organics either visible or inferred	Pt	Light weight, spongy and often elastic at w_n -- shrinks considerably on air drying. Much water squeezes from sample.	w_n – 500 to 1200% γ – 60 to 70 pcf G – 1.2 to 1.8 $C_c/(1+e_o)$=.4+
	FINE GRAINED PEAT (amorphous)			Light weight, spongy but not often elastic at w_n – shrinks considerably on air drying. Much water squeeze from sample.	w_n – 400 to 800% LL – 400 to 900% PI – 200 to 500 γ - 60 to 70 pcf G – 1.2 to 1.8 $C_c/(1+e_o)$=.35 to .44
HIGHLY ORGANIC SOILS	Silty Peat	30 to 75% Organics either visible or inferred	Pt	Relatively light weight, spongy. Thread usually weak and spongy near PL Shrinks on air drying; medium dry strength. Usually can squeeze water from sample readily --slow dilatency.	w_n – 250 to 500% LL – 250 to 600% PI – 150 to 350 γ - 65 to 90 pcf G – 1.8 to 2.3 $C_c/(1+e_o)$=.3 to .4
	Sandy Peat			Sand fraction visible. Thread weak and friable near PL; shrinks on air drying; low dry strength. Usually can squeeze water from sample readily--high dilatency--"gritty."	w_n – 100 to 400% LL – 150 to 300% (plot below A line) PI – 50 to 150 γ – 70 to 100 pcf G – 1.8 to 2.4 $C_c/(1+e_o)$=.2 to .3
ORGANIC SOILS	Clayey ORGANIC SILT	5 to 30% Organics either visible or inferred	OH OL	Often has strong H_2S odor. Thread may be tough depending on clay fraction. Medium dry strength, slow dilatency.	w_n – 65 to 200% LL – 65 to 150% (usually plot at or near A line) PI – 50 to 150 γ – 70 to 100 pcf G – 2.3 to 2.6 $C_c/(1+e_o)$=.20 to .35
	Organic SAND or SILT			Threads weak and friable near PL – or may not roll at all. Low dry strength; medium to high dilatency.	w_n – 30 to 125% LL – 30 to 100% (usually plot well below A line) PI – non-plastic to 40 γ – 90 to 110 pcf G – 2.4 to 2.6 $C_c/(1+e_o)$=.1 to .25
SLIGHTLY ORGANIC SOILS	SOIL FRACTION add slightly Organic	Less than 5% Organics combined visible and inferred	Depend upon inorganic fraction	Depend upon the characteristics of the inorganic fraction.	Depend upon inorganic fractions.

TABLE 6

DESCRIPTION OF SOIL BASED ON OBSERVATION AND TESTS

Typical Name	Description
BOULDERS	Larger than 12 inches in diameter
COBBLES	3 to 12 inches in diameter
GRAVEL	No. 4 sieve to 3 inches in diameter
Coarse to Fine SAND	No. 200 to No. 4 sieve sizes; all particles are visible to the naked eye

	Dilatency Test	Test Tube Test	Plasti-city	Dry Strength	Sticki-ness	Shine Test
fine SAND	rapid	30 sec	none	extremely	none	none
SILT	moderate	50 min	none	very low	none	none
SILT	slow	+50 min	slight	low	none	none
CLAYEY SILT	none	hours	medium	low to high	slight	smooth & dull
SILTY CLAY	none	hours	high	medium to high	moderate to high	moderately slick & smooth
CLAY	none	+24 hours	very high	high to very high	high to very high	slick & waxy
organic SILT	moderate	±50 min	slight to medium	low	none	dull & silky
organic CLAY	none	±24 hrs	medium to high	medium to high	moderate to high	dull, smooth & silky

Unified Soil Classification System

Criteria for Assigning Group Symbols and Names			Soil Classification	Generalized Group Descriptions
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve	GRAVELS More than 50% of coarse fraction retained on No. 4 Sieve	CLEAN GRAVELS Less than 5% fines	GW	Well-graded Gravels
			GP	Poorly-graded gravels
		GRAVELS WITH FINES More than 12% fines	GM	Gravel and Silt Mixtures
			GC	Gravel and Clay Mixtures
	SANDS 50% or more of coarse fraction passes No. 4 Sieve	CLEAN SANDS Less than 5% fines	SW	Well-graded Sands
			SP	Poorly-graded Sands
		SANDS WITH FINES More than 12% fines	SM	Sand and Silt Mixtures
			SC	Sand and Clay Mixtures
FINE-GRAINED SOILS 50% or more passes the No. 200 sieve	SILTS AND CLAYS Liquid limit less than 50	INORGANIC	CL	Low-plasticity Clays
			ML	Non-plastic and Low-Plasticity Silts
		ORGANIC	OL	Non-plastic and Low-Plasticity Organic Clays; Non-plastic and Low-Plasticity Organic Silts
	SILTS AND CLAYS Liquid limit greater than 50	INORGANIC	CH	High-plasticity Clays
			MH	High-plasticity Silts
		ORGANIC	OH	High-plasticity Organic Clays; High-plasticity Organic Silts
HIGHLY ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor		PT	Peat

Component Definitions by Gradation

Component	Size Range
Boulders	Above 12 in.
Cobbles	3 in. to 12 in.
Gravel	3 in. to No. 4 (4.76mm)
Coarse gravel	3 in. to 3/4 in.
Fine gravel	3/4 in. to No. 4 (4.76mm)
Sand	No. 4 (4.76mm) to No. 200 (0.074mm)
Coarse sand	No. 4 (4.76mm) to No. 10 (2.0mm)
Medium sand	No. 10 (2.0mm) to No. 40 (0.42mm)
Fine sand	No. 40 (0.42mm) to No. 200 (0.074mm)
Silt and Clay	Smaller than No. 200 (0.074mm)

Samples

SS	SPT Sampler (2.0" OD)
HD	Heavy Duty Split Spoon
SH	Shelby Tube
P	Pitcher Sampler
B	Bulk
C	Cored

Unless otherwise noted, drive samples advanced with 140 lb. hammer with 30 in. drop.

Relative Density or Consistency, Utilizing Standard Penetration Test Values

Cohesionless Soils (a)			Cohesive Soils (b)		
Density (c)	N, blows/ft. (c)	Relative Density (%)	Consistency	N, blows/ft. (c)	Undrained Shear Strength (d) (psf)
Very loose	0 to 4	0 - 15	Very soft	0 to 2	<250
Loose	4 to 10	15 - 35	Soft	2 to 4	250-500
Compact	10 to 30	35 - 65	Firm	4 to 8	500-1000
Dense	30 to 50	65 - 85	Stiff	8 to 15	1000-2000
Very Dense	over 50	>85	Very Stiff	15 to 30	2000-4000
			Hard	over 30	>4000

(a) Soils consisting of gravel, sand, and silt, either separately or in combination, possessing no characteristics of plasticity, and exhibiting drained behavior.

(b) Soils possessing the characteristics of plasticity, and exhibiting undrained behavior.

(c) Refer to text of ASTM D 1586-84 for a definition of N; in normally consolidated cohesionless soils Relative Density terms are based on N values corrected for overburden pressures.

(d) Undrained shear strength = 1/2 unconfined compression strength.

Laboratory Tests

Test	Designation
Moisture	(1)
Density	D
Grain Size	G
Hydrometer	H
Atterberg Limits	(1)
Consolidation	C
Unconfined	U
UU Triax	UU
CU Triax	CU
CD Triax	CD
Permeability	P

(1) Moisture and Atterberg Limits plotted on log.

Descriptive Terminology Denoting Component Proportions

Descriptive Terms	Range of Proportion
Trace	0-5%
Little	5-12%
Some or Adjective (a)	12-30%
And	30-50%

(a) Use Gravelly, Sandy or Silty as appropriate.

Silt and Clay Descriptions

Description	Typical Unified Designation
Silt	ML (non-plastic)
Clayey Silt	CL-ML (low plasticity)
Silty Clay	CL
Clay	CH
Plastic Silt	MH
Organic Soils	OL, OH, Pt

FIGURE 1
SOIL CLASSIFICATION
TP-1.2-6

PROJECT:

RECORD OF BOREHOLE BH-01

SHEET 1 **OF** 2

DATUM: MSL

PROJECT NUMBER:

BORING LOCATION:

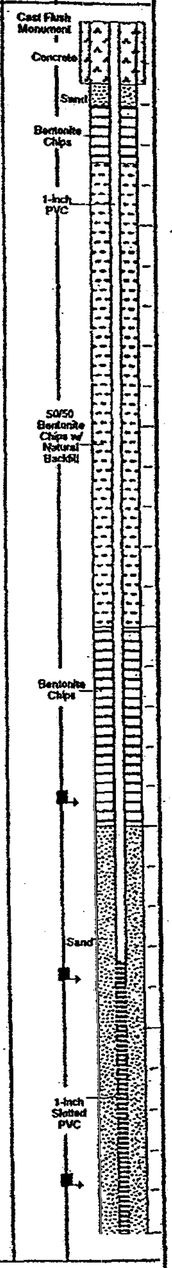
BORING DATE:

DEPTH FEET	BORING METHOD	SOIL PROFILE: DESCRIPTION	USCS	ELEV. / DEPTH	SAMPLE NUMBER	TYPE	BLOWS / 6 IN. (140 lb. hammer, 30 inch drop)	N	REC/ATT
0	4-inch HSA	Loose, brownish black (5R 2/2), unstratified fine SAND and SILT, contains roots and other organics, (OL) (TOPSOIL)	OL	121.0 / 120.5 / 0.5					
		Compact, dark yellowish brown (10YR 4/2), unstratified, fine to coarse SAND and SILT, little to trace fine to coarse Gravel, (SM)	SM	117.0 / 4.0					
5		Loose to very dense, dark yellowish brown (10YR 4/2), unstratified fine to coarse SAND, some to little fine to coarse Gravel, some to little Silt, (SM) (RECESSIONAL DRIFT - Qvr)	SM		1	SS	10-15-11	26	0.5/1.5
10					2	SS	4-3-4	7	0.9/1.5
15					3	SS	5-7-14	21	0.6/1.5
					4	SS	17-33-27	>50	1.2/1.5
20		Very dense, dark yellowish brown (10YR/4/2), unstratified, fine to coarse SAND and fine to coarse GRAVEL, some to little Cobbles, some to little Silt, trace Boulders, (SM to GM) (RECESSIONAL DRIFT - Qvr)	SM to GM	101.0 / 20.0					
					5	SS	50/0.4	>50	0.4/0.4
25									
					6	SS	12-31-35	>50	1.1/1.5
30		Log continued on next page							

PENETRATION RESISTANCE BLOWS/FT. ■ 0 10 20 30 40 50

WATER CONTENT PERCENT Wp W Wl

PIEZOMETER GRAPHIC / WATER LEVEL



EXAMPLE

DRILL RIG:

DRILLING CONTRACTOR:

DRILLER:

LOGGED:

CHECKED:

DATE:

Golder Associates

FIGURE **2**
RECORD OF BOREHOLE FORM
TP-1.2-6

1.0 PURPOSE

This Technical Procedure is to be used to establish a uniform procedure for executing rising head and falling head slug tests.

2.0 APPLICABILITY

This Technical Procedure is applicable to all persons or parties involved with rising head and falling head slug testing.

3.0 DEFINITIONS

3.1 Rising Head Slug Test: A controlled field experiment conducted in a single borehole to determine the hydraulic properties of water-bearing rocks. The test is performed by measuring water level recovery in a well as a function of time, following near instantaneous withdrawal of water.

3.2 Falling Head Slug Test: A controlled field experiment conducted in a single borehole to determine hydraulic properties of water-bearing rocks. The test is performed by measuring water level recovery in a well as a function of time, following near instantaneous addition of water or a solid rod.

3.3 Measuring Point: A permanent point to which water level measurements are referenced. Top of the borehole casing is commonly utilized as a measuring point.

3.4 Displacement: Change in water level from static condition.

4.0 REFERENCES

Bouwer, H. and R.C. Rice, 1976. *A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells.* Water Resources Res., Vol. 12, pp. 423-428.

Cooper, H.H., J.D. Bredehoeft, and I.S. Papadopulos, 1967. *Response of a finite-diameter well to an instantaneous charge of water.* Water Resources Res., Vol. 3, pp. 263-269.

Kruseman, G.P. and N.A. de Ridder, 1990. *Analysis and Evaluation of Pumping Test Data. (Chapter 16 Slug Tests).* Second Edition. International Institute for Land Reclamation and Improvement/ILRI. Wageningen, The Netherlands.

Uffink, G.J.M., 1984. *Theory of the oscillating slug test.* Nati. Institute for Public Health and Environmental Hygiene, Bilthoven. Unpublished research report, 18 pp. (in Dutch).

5.0 DISCUSSION

The outline of this procedure table around the well assumes negligible drawdown of the water and no flow above the water table.

6.0 RESPONSIBILITY

6.1 Each Field Engineer performing a rising head or falling head slug test shall be responsible for proceeding with testing in compliance with this technical procedure.

6.2 Task Leader shall be responsible for:

- Direct supervision of personnel performing the test.
- Assurance that equipment and materials are available to permit accomplishment of the task.
- Determine duration of water level monitoring.
- Determine time intervals between readings and depth of suction hose.

7.0 EQUIPMENT AND MATERIALS

7.1 Data sheets for slug test-field record (Exhibit A)

7.2 Water level sounder accurate to a minimum of 0.03 feet.

7.3 Stop watch.

7.4 Field notebook.

7.5 Folding rule or spring-wound tape measure.

7.6 A pump or bailer of suitable design to evacuate the water from the well bore rapidly for rising head test, or a slug rod of the appropriate diameter for falling and rising head tests (preferred).

7.7 Hoses of sufficient length and annular rigidity to convey water under expected pressures (if using a pump).

7.8 Semilog graph paper.

7.9 Pressure transducer, datalogger, and software.

7.10 Laptop computer.

8.0 PROCEDURE

General Pre-test Setup and Monitoring

8.1 Record data at top of Rising/Falling Head Slug Test Field Record data sheets (Exhibit A).

8.2 If using pressure transducer and datalogger, install pressure transducer in well, taking care to submerge transducer sufficiently so that it will be at sufficient depth to avoid being damaged when a slug rod, bailer, or pump is lowered into the well for the test. Program transducer and data logger to collect test data.

8.3 Monitor water level for a time period of at least 1/4 of the anticipated test duration to determine static water level or water level trends. Refer to Golder Associates Quality Assurance TP-1,4-6 for instructions on measurements of water levels. Measurements shall be taken as depth below a specific permanent measuring point (i.e. northwest rim top of casing).

8.4 Use water level sounder to sound depth of water and record. Start transducer and data logger for test data collection.

Falling Head Test

8.5 Insert slug rod rapidly into well casing below the static water level, taking care not to damage transducer, to predetermined depth, and record water level decline. Keep slug rod in well until the water level recovers to pre-test levels. Once the water level recovers to the pretest level, a rising head test can be performed (see next section). If using a transducer and datalogger, download the test data and perform a preliminary assessment of the data quality. If using a water level tape, plot the data to perform a preliminary assessment of the data quality.

Rising Head Test

8.6 Reprogram the transducer to collect data from a new test. Monitor the water level for a time period of at least 1/4 of the anticipated test duration to determine static water level or water level trends.

8.7 If using a pump, start pump and operate at full throttle. When water level reaches suction intake start stop watch and remove suction line from well casing; then shut off pump.

8.8 If using a bailer or slug rod, rapidly remove bailer or slug rod from hole, Start/stop watch when bailer begins to be removed from the hole.

8.9 Monitor and record rising water levels and their time of occurrence as frequently as possible until the static water level is reached.

8.10 Check data by downloading the transducer and plotting log drawdown versus time, or manually plotting the data.

8.11 Deem test unsuccessful and reapply if less than 3 points were recorded, or if data do not plot with reasonable linearity (see Bouwer, 1978, p. 117).

8.12 Calculate geometric factors necessary for data analysis and record on Exhibit B, "Geometric Factors for Rising Head Slug Test Analysis" and perform data analysis as described by Bouwer, 1978, Cooper et al. 1967, or Uffink 1984 (see Appendix A).

Job No. ____
Job Name ____
By ____
Date ____

EXHIBIT A
RISING HEAD SLUG TEST FIELD RECORD

Well Identification____ Test No.____

Measuring Point Description____
Measuring Point Elevation____ (datum:)____

Radius of Well Casing (r_c)____
Radius of Well plus developed zone outside casing (r_w)____

Depth of Well (Below measuring point [BMP])____
Height of screened or uncased section of well (L_e)____

Static Depth of Water (BMP)____
Depth of Suction Line (BMP)____

Time	Depth to Water	Drawdown	Remarks

Page _____ of _____

Job No. ______________

Job Name ______________

By ______________

Date ______________

Well Identification ______________________ Test No. ______________

Time	Depth to Water	Drawdown	Remarks

Job No. ____________

Job Name ____________

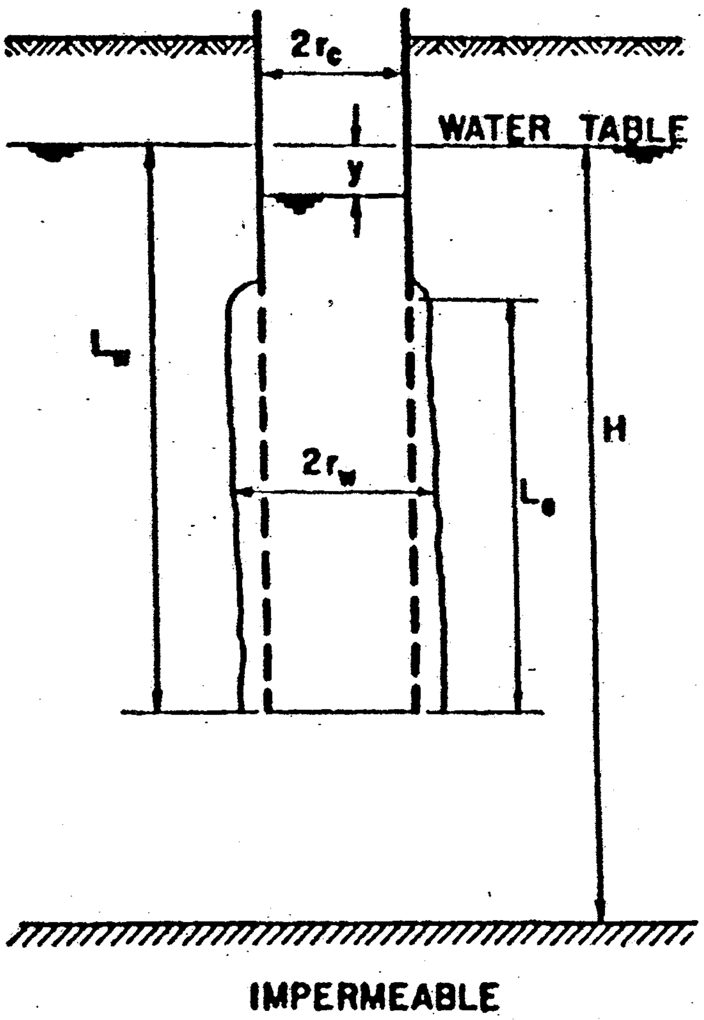
By ____________

Date ____________

EXHIBIT B

GEOMETRIC FACTORS FOR RISING HEAD SLUG TEST ANALYSIS

Well Identification ____________



(See Bouwer, 1978, Appendix A for explanation of symbols)

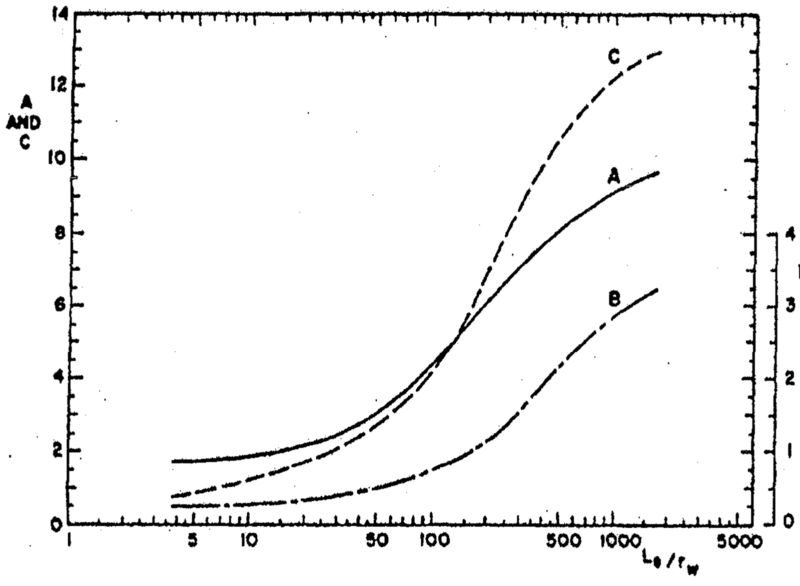


Figure 5.11 Curves relating coefficients A, B, and C to L_e/r_w.

aquifer), the term $\ln[(H - L_w)/r_w]$ in Eq. (5.42) cannot be used. For this situation, the equation for $\ln(R_e/r_w)$ is

$$\ln\frac{R_e}{r_w} = \frac{1}{\dfrac{1.1}{\ln(L_w/r_w)} + \dfrac{C}{(L_e/r_w)}} \tag{5.43}$$

where C is a dimensionless coefficient shown in Figure 5.11 as a function of L_e/r_w. The value of $\ln(R_e/r_w)$ calculated with Eqs. (5.42) and (5.43) is within 10 percent of the analog value if $L_e > 0.4L_w$ and within 25 percent if $L_e < 0.2L_w$.

Since K, r_c, R_e, r_w, and L_e are constant for a given well, $1/t \ln(y_0/y_t)$ must also be constant, as indicated by Eq. (5.41). Thus, when the observed values of y are plotted against t on semilogarithmic paper (y on the log scale), the data points should form a straight line. This is exemplified in Figure 5.12, showing data from a slug test on a well in the Salt River bed west of Phoenix, Arizona (see Problem 5.7). The data begin to deviate from a straight line at small y, probably because of measurement error. The straight-line portion of the points should be used to evaluate $1/t \ln(y_0/y_t)$ for calculation of K.

The time $t_{90\%}$, necessary for the water level in the well to rise 90 percent of the distance back to the equilibrium level, is given by the equation (Bouwer and Rice, 1976)

$$t_{90\%} = 0.0527\frac{r_c^2}{KL_e}\ln\frac{R_e}{r_w} \tag{5.44}$$

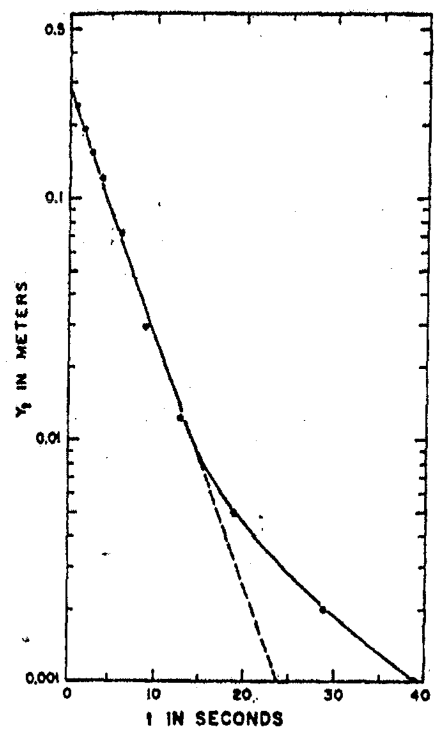


Figure 5.12 Plot of y versus t for slug test on East Well.

If K and/or L_e are relatively large, $t_{90\%}$ may be only a few seconds. Such fast water-level rises can be measured with sensitive pressure transducers and fast strip-chart recorders or x-vs.-y plotters to record the transducer output.

Although streamlines in flow systems around slug-tested wells contain both vertical and horizontal portions, most of the head loss is dissipated in a horizontal direction (Bouwer and Rice, 1976). Thus, K yielded by the slug test primarily reflects K in horizontal direction. The portion of the aquifer on which K is measured is approximately a cylinder with a radius of about R_e and a height slightly larger than L_e. The T value of the aquifer is obtained by multiplying K by H, assuming of course that the aquifer is uniform.

Since the water table in the aquifer was held at a constant level and taken as a plane source of water in the analog evaluations of R_e, the slug test of Bouwer and Rice can also be used to estimate K of confined aquifers that receive most of their water from the upper confining layer, through leakage or compression.

5.3.1 Slug Test

Cooper et al. (1967) obtained a solution of Eq. (4.21) to calculate T and S of confined aquifers from the rate of rise of the water level in a fully penetrating well after a sudden removal of a slug of water. Type curves were prepared so that T and S could be evaluated by matching field data with type curves, similar to the Theis procedure for pumping tests. The S value obtained with this technique may not be reliable because the shape of the type curves is rather insensitive to S (Lohman, 1972).

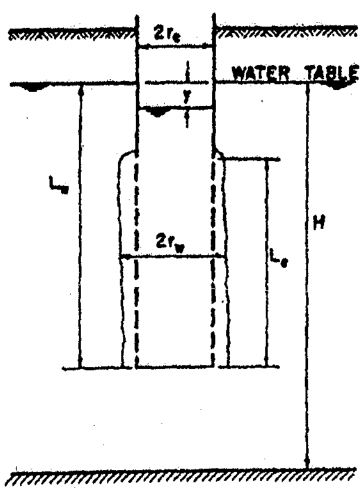


Figure 5.10 Geometry and symbols of partially penetrating, partially perforated well in unconfined aquifer with gravel pack or developed zone around perforated section.

A slug-test procedure applicable to fully or partially penetrating wells in unconfined aquifers was developed by Bouwer and Rice (1976). The procedure is based on the Thiem equation (4.3) and assumes negligible drawdown of the water table around the well and no flow above the water table. The term $h_2 - h_1$ in Eq. (4.3) then represents the distance y of the water level in the well below the water table (Figure 5.10). The rate of rise dy/dt of the water level after removal of water is expressed as

$$\frac{dy}{dt} = -\frac{Q}{\pi r_c^2} \tag{5.40}$$

where r_c is the radius of the well section where the water level is rising and Q is the flow of groundwater into the well. The minus sign in Eq. (5.40) is introduced because y decreases with increasing t, so that dy/dt is negative. Substituting the Thiem equation (4.3) for Q in Eq. (5.40), integrating, and solving for K yields

$$K = \frac{r_c^2 \ln (R_e/r_w)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t} \tag{5.41}$$

where R_e = effective radial distance over which the head difference y is dissipated
r_w = radial distance between well center and undisturbed aquifer (r_c plus thickness of gravel envelope or developed zone outside casing)
L_e = height of perforated, screened, uncased, or otherwise open section of well through which groundwater enters
y_0 = y at time zero
y_t = y at time t
t = time since y_0

The effective radius R_e is essentially the effective value of r_2 to be used in Eq. (4.3) so that it gives the correct value of Q (the Thiem equation was developed for horizontal flow only and as such cannot be used to calculate Q for the system of Figure 5.10). Values of R_e were experimentally determined with a resistance network analog for different values of r_w, L_e, L_w and H (see Figure 5.10 for meaning of symbols). The following empirical equation was then developed to relate R_e to the geometry and boundary conditions of the system

$$\ln \frac{R_e}{r_w} = \frac{1}{\dfrac{1.1}{\ln (L_w/r_w)} + \dfrac{A + B \ln [(H - L_w)/r_w]}{(L_e/r_w)}} \tag{5.42}$$

where A and B are dimensionless parameters shown in Figure 5.11 in relation to L_e/r_w. If H is much larger than L_w, a further increase in H has little effect on the flow system and, hence, on R_e. The analog analyses indicated that the effective upper limit of $\ln [(H - L_w)/r_w]$ is 6. Thus, if $H - L_w$ is so large that $\ln [(H - L_w)/r_w] > 6$, a value of 6 should still be used for this term in Eq. (5.42), including the theoretical case of $H = \infty$. If $H = L_w$ (well penetrating to bottom of

RECORD OF REVISION
TP-1.2-18
Rev. 5

Section	Description of Revision
Throughout	Minor editorial changes and clarifications
8.8 and Exhibit B	Added requirements for Field Change Request

1. PURPOSE

This technical procedure establishes uniform methods for sampling surface soils for chemical analysis.

2. APPLICABILITY

This Technical Procedure shall be used by all Golder Associates Inc. (Golder) personnel sampling surface soils for chemical analysis.

3. DEFINITIONS

3.1 Surface Soil

Surface soil is defined as consolidated soil on the land surface or as exposed by an excavation or boring within twenty (20) feet of the land surface.

3.2 Sampling Interval

The sampling interval is defined as the stratigraphic depth represented by the soil sample.

3.3 In Situ Soils

The term in-situ soils refers to soils as they occur in place within the soil column.

4. REFERENCES

Golder Associates Technical Procedure TP-1.2-23, "Chain of Custody."

Golder Associates Technical Procedure TP-1.1-2, "Geodetic Surveys."

5. DISCUSSION

None

6. RESPONSIBILITIES

6.1 Sampling Technician

The Sampling Technician is responsible for completing the sampling assignment in accordance with this Technical Procedure and governing project plans or instructions.

6.2 Task Leader

The Task Leader is responsible, within the guidelines of governing plans or instructions, for determining which soils shall be sampled and for monitoring the sampling process to ensure that procedures and documentation are in accordance with this document.

6.3 Project Manager

The Project Manager or a qualified designee is responsible for determining the type of chemical analyses to be performed on soil samples, and for defining such requirements to project staff through appropriate plans or instructions.

7. EQUIPMENT AND MATERIALS

- Brunton compass, 0° to 360° divisions;
- site map and clipboard;
- bound field logbook or field report forms (Exhibit A);
- assorted standard field equipment (e.g., hammers, post-hole digger, shovel, hand auger) for exposing soils to be sampled;
- measuring tape;
- engineer's rule (six feet long, with 0.10 foot graduations);
- indelible ink pens;
- two-inch wood stakes and colored flagging material;
- if required, sampling equipment appropriate for soils to be analyzed for non-volatile constituents; all such equipment shall be metal (steel, stainless steel or aluminum) and may include hand augers, hand scoops, sampling thiefs, sampling dredges, core samplers, or sampling triers. If volatile constituents are to be analyzed in the soil samples, sampling equipment shall be designed to minimize exposure to the atmosphere. As an example, a metal drive tube appropriate for the size of the soil particles and slightly smaller in diameter than the wide-mouth glass sample bottles may be used, with appropriate sample extraction accessories;
- sample bottles, sized appropriately for the desired sample and soil particle size;
- Chain of Custody records, seals, and sample labels as required by procedure TP-1.2-23, "Chain of Custody";
- appropriate decontamination solutions such as organic free distilled/deionized water, non-phosphate detergent, tap water;
- decontamination equipment such as brushes and sprayers, and drums or applicable plan or containers for capturing decontamination waste solution; and

- thermometer controlled in accordance with Golder's quality procedure for calibration of measuring and test equipment.

8. PROCEDURE

8.1 Sample Location

Location mapping shall be to the level of detail required by the applicable plan or instructions, and sound engineering and geologic practice. If the base map for the sampling site is of sufficient accuracy, the sample location may be approximated within a 10' radius and physically identified by a wood stake marker. If the base map does not have the required accuracy, locations shall be described by either (1) tape measurement from three permanent features identifiable on the base map; (2) measured along a compass bearing from a permanent feature; or (3) triangulated with compass bearings from three permanent features identifiable on the base map. Compasses may be used only when the site does not contain magnetic or large metal objects. The locations so derived will be identified by a wood stake marker with test pit designation, and recorded as described in Section 8.2. When required by project directive, all location markers will be geodetically surveyed in accordance with TP-1.1-2, "Geodetic Surveys."

8.2 Documentation

Final sample location, sample types and numbers, and relevant sampling events (including on-site personnel and all visitors) shall be recorded on Field Report forms (Exhibit A) or bound field logbooks. Events shall be recorded chronologically, with the time of each event noted.

8.3 Decontamination

All sampling equipment shall be decontaminated prior to the start of sampling activities and between each use. Unless other decontamination procedures are specified in the project plans or instructions, the following steps will be followed. The sampling equipment shall be washed with non-phosphate detergent solution. Brushes shall be used to aid in removing all visible soil or grit. A tap water rinse shall be used to thoroughly remove all detergent solution. The final rinse shall be with organic free distilled/deionized water. All waste wash solutions shall be captured and disposed of in the manner defined by the applicable project plan or instruction, in compliance with applicable regulatory requirements.

8.4 Sampling

The soils to be sampled shall be exposed prior to sample acquisition. If the upper six inches of soils are to be sampled, then surface vegetation shall be removed. If samples are to represent discrete depth intervals below land surface, then overlying soils shall be removed by a shovel, post-hole digger, hand auger, or other appropriate method to the desired interval. For loose watery sediments from stream bottoms, a pond sampler, sampling dredge, pail, or ladle can be used. The sediment sample should be allowed to settle and the extra water decanted prior to transferring samples to containers. For cohesive wet or dry stream-bottom samples, a vertical-pipe, sampling dredge, or core sampler can be used and driven into the stream bed to the selected depth. An in-situ soil sample shall be obtained from the desired sampling interval. If the required analyses do not include volatile constituents, an in-situ soil sample can be obtained using a hand scoop, hand auger, sampling thief, or sampling trier. The soils shall be visually inspected and immediately put into the appropriate sample bottle as required by the governing project plan or instruction. No preservatives shall be added to the sample.

If soils are to be analyzed for volatile constituents, the sample shall be obtained from the desired interval using a drive tube sampler. Contact between the atmosphere and the sample must be minimized; the drive tube sampler shall be driven into the materials with a hammer, and the sample extruded directly into the appropriate sample bottle. An air-tight cap shall be immediately placed on the sample bottle; no preservatives shall be added.

If a backhoe is used to expose sampling intervals for analysis of volatile constituents, a hand auger or drive tube may be used to sample the test pit walls or floor when the test pit is less than four (4) feet deep. If the test pit is greater than four (4) feet, a relatively undisturbed sample may be obtained from the backhoe bucket using a drive tube sampler.

8.5 Composite Samples

If soil sample composites are to be established, equal volumes of individual samples shall be added together for the composite sample. At least three small, equal sized samples from several points within a five foot radius shall be collected. Samples will be placed into a clean, decontaminated stainless steel container and each portion will be stirred together into one composite. The composite sample shall be given an individual sample number, and the sample number of each contributing sample recorded in the field logbook or Field Report form.

8.6 Sample Labeling, Handling, and Shipment

Samples shall be immediately labeled, sealed with a tamper-proof seal and relevant data recorded on individual Chain of Custody forms as required by TP-1.2-23, "Chain of Custody." Samples shall be placed in a chilled cooler at approximately 4° C, ± 2°C, as soon as possible. A thermometer shall be placed in the cooler for temperature monitoring purposes. The cooler shall remain in sight of the Sampling Technician at all times, or be kept in locked storage, as required by TP-1.2-23.

Samples shall be forwarded to the analytical laboratory accompanied by the Chain of Custody record, in compliance with TP-1.2-23 requirements. When samples are ready for shipment, the Task Leader shall release the sample to the carrier, who shall also sign the custody form. The Chain of Custody form is in triplicate. One copy of the form shall be retained by the Task Leader; the original form and the remaining copy shall be shipped with the sample. Upon receipt at the laboratory, the laboratory custodian shall verify the integrity and identification of the sample, sign the form, and return the original copy to the Task Leader or Project Manager. All originals shall be retained in the project records.

8.7 Site Restoration

Any excavation or hole made to obtain samples shall be backfilled with the excess material removed from the hole, unless other requirements are invoked by governing plans or instructions.

8.8 Field Change Request

Variation from established procedure requirements may be necessary due to unique circumstances encountered on individual projects. All variations from established procedures shall be documented on a Field Change Request form (Exhibit B) and reviewed by the Project Manager and the QA Manager.

The Project Manager may authorize individual Field Engineers to initiate variations as necessary. If practical, the request for variation shall be reviewed by the Project Manager and the QA Manager prior to implementation. If prior review is not possible, the variation may be implemented immediately at the direction of the Field Engineer, provided that the Project Manager is notified of the variation within 24 hours of implementation, and the Field Change Request is forwarded to the Project Manager and QA Manager for review within 2 working days of implementation. If the variation is unacceptable to either reviewer, the activity shall be reperformed or action shall be taken as indicated in the Comments section of the Field Change Request form.

All completed Field Change Request forms shall be maintained in the project records.

TP1218.RV5

GOLDER ASSOCIATES
4104 148th Avenue NE
Redmond, Washington 98052

(206) 883-0777

DATE	JOB NO
PROJECT	
LOCATION	
CONTRACTOR	OWNER
WEATHER	TEMP °at AM °at PM
PRESENT AT SITE	

TO ______________________

THE FOLLOWING WAS NOTED:

COPIES TO ______________________

FIELD REPORT

SIGNED ______________________

EXHIBIT **A**
FIELD REPORT
TP 1.2-18

FIELD CHANGE REQUEST

Golder Associates

Job/Task Number:

Other Affected Documents:

Requested Change:

Reason for Change:

Change Requested by: Date

Reviewed by: Date
GAI Project Manager

Comments:

Reviewed by: Date
GAI QA Manager

Comments:

EXHIBIT B
FIELD CHANGE REQUEST FORM
TP-1.2-18

TP-1.2-21
Rev. -3-
Record of Revisions

Section	Description of Revision
Throughout	Editorial and format revisions throughout
6.	Included responsibilities for site access restrictions and utility locate
7.	Added pocket penetrometer and camera and film to equipment list
8.1	Added new, Utility Locate section
8.6	Added new, photo requirement
8.7 & Exhibit D	Changed Procedure Alteration Checklist to Field Change Request

1. PURPOSE

The purpose of this technical procedure is to establish a uniform methodology for logging and sampling of soil exposed in test pits for geotechnical engineering purposes.

2. APPLICABILITY

This procedure shall apply to all routine logging and sampling of test pits for geotechnical engineering purposes for projects managed by Golder Associates' Redmond, Washington office. This procedure may be invoked for activities conducted from other Golder Associates offices upon management request.

3. DEFINITIONS

3.1 Test Pit: A test pit is a supported or nonsupported excavation created to expose surficial soils for in-situ geologic examination and/or sampling.

3.2 Test Pit Logging: Test pit logging consists of direct observation, identification, interpretation, and documentation of geologic information exposed in the vertical or near-vertical walls of test pit excavations.

3.3 Geotechnical Sample: A geotechnical sample is a soil sample retrieved from a test pit excavation for purposes of physical properties testing in support of geotechnical and civil engineering investigations. When such samples support environmental remediation activities or are collected in areas known to be contaminated with hazardous wastes, a greater level of care is required to preserve and document sample identification, integrity, traceability, and in-situ characteristics. Hazardous geotechnical samples are subject to the full range of chain of custody controls described in TP-1.2-23, "Chain of Custody."

4. REFERENCES

4.1 Golder Associates Inc. Technical Procedure TP-1.2-6, "Field Identification of Soil."

4.2 Golder Associates Inc. Technical Procedure TP-1.2-18, "Technical Procedure for Sampling Surface Soil for Chemical Analysis."

4.3 Golder Associates Inc. Technical Procedure TP-1.2-23, "Chain of Custody."

5. DISCUSSION

Test pit logging and sampling activities are routinely performed to define subsurface site conditions for prospective engineering projects. Depending on the type of site and the purposes of the investigation, test pit logging and sampling may be the only subsurface method used, or may be used in conjunction with other methods. The logging methods discussed in this procedure are suitable only for general geotechnical engineering purposes, and are not intended to provide the level of detail or documentation necessary in trench excavations (which are normally required for detailed fault analyses, for site characterization of nuclear facilities, or for other major construction projects with extensive subsurface investigation requirements). The sampling techniques described in this procedure provide the means for obtaining both disturbed and undisturbed samples for physical properties testing. If it is necessary to retrieve samples for chemical analysis, sampling methods shall be in compliance with TP-1.2-18, "Technical Procedure for Sampling Surface Soil for Chemical Analysis."

6. RESPONSIBILITIES

6.1 Field Geologist/Engineer: All Field Geologists/Engineers assigned test pit logging and sampling responsibilities are responsible for compliance with this procedure. Field Geologists/Engineers are responsible for directing the activities of their subcontracted backhoe test pit exploration or excavator operator, and for accurately and thoroughly documenting all site activities. They are responsible for verifying with the Project Manager that there are no site access restrictions and a utility locate has been performed. In situations in which unexpected environmental contaminants or hazards to personnel are encountered, Field Geologists/Engineers are responsible for immediately ceasing work and notifying the Project Manager.

6.2 Project Manager: Project Managers are responsible for ensuring that all Field Geologists/Engineers assigned logging and sampling responsibilities have been properly trained in the requirements of this procedure. On-the-job training under the guidance of an experienced Field Geologist/Engineer is permitted at the discretion of the Project Manager, provided that the training is properly documented by a memo to file. Project Managers are responsible for securing site access permission, conducting a utility locate, defining the pit specifications, the required level of detail for logging, the number and type of samples to be retrieved, and the required type of physical analyses. Project Managers are also responsible for development and implementation of site specific safety plans for investigations at known hazardous waste sites.

7. EQUIPMENT AND MATERIALS

- site map
- Brunton compass
- tape measures
- pocket penetrometer
- 6 ft. engineer's folding rule
- pit marking materials (flagging, stakes, and nails)
- standard Field Report Forms (Exhibit A)
- camera and film

- standard Field Test Pit Log forms (Exhibit B)
- other standard field support equipment (rock hammer, trowel, shovel, pen, magnifying glass, color chart, copy of TP-1.2-6, copy of this procedure, adhesive sealing tape, etc.)
- hard hat
- Shelby tube sampler, with extra tubes and caps
- plastic or cloth sample bags, sample bottles, or plastic buckets
- as required
- sample labels (Exhibit C)

Additional equipment required for hazardous waste sites may include:

- oxygen analyzer and organic vapor monitor
- respirator, tyvek suit, gloves, and other personal protective gear as required by the project-specific site safety plan or other safety directive
- sample labels and seals (Exhibit C)
- chain-of-custody records (see TP-1.2-23, "Chain of Custody")
- sampling tool decontamination solutions, such as non-phosphate detergent, tap water, and acetone
- decontamination equipment such as brushes and pressure washers, with containers for capturing waste solutions

8. PROCEDURE

8.1 Utility Locate

Prior to beginning test pit excavations it is the responsibility of the Field Engineer/Geologist to check the utility locate marks to determine that no utilities exist near the test pit area. Underground utilities are normally marked at the ground surface with spray paint. The color of the paint normally indicates the type of buried utility.

- red - power
- yellow - gas
- blue - water
- orange - cable, TV, phone
- green - sewers

Test pit excavations should be kept a minimum of 15 feet from buried utilities. Some larger utilities such as gas mains, fuel product lines, and most large water mains may specify greater setbacks. If utilities conflict with planned test pit locations the Project Manager should be notified to adjust the locations.

8.2 Test Pit Location and Location Control

Test pit locations may be defined by the Project Manager, or may be defined by the Field Geologist/Engineer at the Project Manager's discretion. When the location is determined by the Field Geologist/Engineer, it is important that an appropriate and sufficient number of exposures be developed to permit development of an adequate geologic map of the site. Any observed anomalies and features which may potentially constitute geologic hazards must be followed up in the field, and additional pits excavated as necessary. All pits should be marked with a flagged stake that has been marked with the test pit number on both sides. The stake should be located at one corner of the excavation, and should be surveyed or related to a known survey point by measurement and compass bearing. The dimensions and compass bearing of the pit with relation to the stake must be determined. All location information shall be recorded on the Field Test Pit Log (Exhibit B), Field Report form (Exhibit A), or site location map as appropriate.

8.3 Test Pit Logging

The most detailed logging will be occur in the upper 3 to 4 feet of the pit where direct access to the pit walls is possible. Below that level, the distribution of soil units shall be based on visual observation and on examination of the excavated material. **IN NO CASE SHALL GOLDER ASSOCIATES PERSONNEL ENTER AN UNSUPPORTED TEST PIT GREATER THAN 4 FEET IN DEPTH.** On hazardous waste sites, oxygen analyzer and organic vapor analyzer scans shall be performed prior to any entry into the pit; respirator and personal protective equipment use shall be as specified by site specific safety plans. Depth from the ground surface to the various soil units shall be determined by a tape measure suspended from the surface; the backhoe or excavator operator may be requested to clean portions of the pit or to retrieve bucket samples from particular locations in order to aid in the recording of stratigraphy or in the collection of samples. All soils shall be identified and described on the Field Test Pit Log in compliance with TP-1.2-6, "Field Identification of Soil." The relative soil density shall be estimated, and the depth to groundwater level and time of observation shall be noted on the Field Test Pit Log. Seepage shall be noted wherever encountered and an estimate of the flow rate recorded. Observations on the relative difficulties encountered by the backhoe in excavating particular materials shall be recorded, along with the relative stability of the test pit sidewalls.

8.4 Test Pit Sampling

The Field Engineer/Geologist shall retrieve representative samples of each different soil type encountered during the investigation. Disturbed samples may be retrieved directly from the backhoe bucket or from within the pit using a shovel, scoop, or trowel; "undisturbed" samples may be retrieved from the excavation with a thin-walled (Shelby) tube sampler. Required sample volumes and specific considerations for particular sample types shall be specified by the Project Manager. Bulk samples shall be marked or tagged with the project number, test pit number, sample number, sampled depth interval, date, and "Golder Associates Inc." The sample number and test pit number should be marked in at least two locations as a precaution against effacement in transit to the geotechnical laboratory. Smaller bottled samples may be labeled with a standard Golder Associates soil sample label (see

Exhibit C). Contaminated samples shall be sealed (see Exhibit C), and a chain of custody form initiated as described by TP-1.2-23, "Chain of Custody."

8.5 Equipment Decontamination

On hazardous waste sites, the backhoe bucket and all sampling equipment shall be decontaminated after use. The sampling equipment shall be cleaned with a brush or pressure sprayer and non-phosphate detergent solution, rinsed with tap water, and, if necessary, rinsed again with acetone if organic compounds are in evidence. All wash fluids shall be captured and properly disposed of as specified by the Project Manager.

8.6 Test Pit Closure

Unless otherwise directed by the Project Manager, all pits shall be backfilled with the excavated soil after completion of all logging and sampling activities. A photo of the completed test pit should be taken prior to backfilling. The photo number and test pit number should be recorded on a photo log, so the photos can be labeled. The pit location stake should remain intact; if it must be moved to backfil the pit, it should be replaced, the location re-established, and recorded on the Field Test Pit Log. For safety purposes, any pit that must be left open overnight shall have its perimeter fenced and flagged, and ladder or other means of escape provided.

8.7 Field Change Requests

Variation from established procedure requirements may be necessary due to unique circumstances encountered on individual projects. All variations from established procedures shall be documented on Field Change Request form (Exhibit D) and reviewed by the Project Manager and the QA Manager.

The Project Manager may authorize individual Geologist/Field Engineers to initiate variations as necessary. If practical, the request for variation shall be reviewed by the Project Manager and the QA Manager prior to implementation. If prior review is not possible, the variation may be implemented immediately at the direction of the Geologist/Field Engineer, provided that the Project Manager is notified of the variation within 24 hours of implementation, and the Field Change Request is forwarded to the Project Manager and QA Manager for review within 2 working days of implementation. If the variation is unacceptable to either reviewer, the activity shall be reperformed or action shall be taken as indicated in the Comments section of the Field Change Request form.

Golder Associates
4104 148th Avenue NE
Redmond, Washington 98052

(206) 883-0777

DATE	JOB NO.
PROJECT	
LOCATION	
CONTRACTOR	OWNER
WEATHER	TEMP ° at AM ° at PM
PRESENT AT SITE	

TO

THE FOLLOWING WAS NOTED:

>

>

COPIES TO

FIELD REPORT

SIGNED

EXHIBIT A
FIELD REPORT FORM
TP-1.2-21

IP3 1024/64966

Golder Associates Inc.

Golder Associates

FIELD TEST PIT LOG

Temp. ______ Weather ______________________ Engineer ____________ Operator ______ Test Pit ________

Equipment ______________________________ Contractor ______________________ Date __________

Location ______________________________ Elevation ____________ Datum ________ Job __________

W ← → E

0 5 10 15 20

0 5 10 15 20

Samples	
No	Depth

Sample Descriptions and Excavation Notes	Time	Depth of Hole	Depth to W/L

Special Notes

EXHIBIT B
FIELD TEST PIT LOG
TP-1.2-21

Golder Associates

Location ______________________

Job No. ________ Date ________

Boring No. ______ Sample No. ______

Depth ________ Blows ________

Description ______________________

____

____

____

Driller ________ Engr. ________

Geotechnical Sample Label

Golder Associates
Seal Number
2455

Golder Associates

Sent By: ______________

Date: ______________

Tamper Proof Seal

FIELD CHANGE REQUEST

Golder Associates

Job/Task Number: ______________________

Other Affected Documents: ______________________

Requested Change: ______________________

Reason for Change: ______________________

Change Requested by: ______________________ Date ____________

Reviewed by: ______________________ Date ____________
GAI Project Manager

Comments: ______________________

Reviewed by: ______________________ Date ____________
GAI QA Manager

Comments: ______________________

EXHIBIT **D**
FIELD CHANGE REQUEST FORM
TP-1.2-21

Record of Revision
TP-1.2-23
Revision Level -1-

Section	Description of Revision
Throughout	Editorial changes and clarifications
8.2	Revised temperature requirement to 4°C ± 2°
8.8 and Exhibit D	Changed Procedure Alteration Checklist to Field Change Request

1. PURPOSE

This technical procedure establishes the requirements for documenting and maintaining environmental sample chain of custody from point of origin to receipt of the sample at the analytical laboratory.

2. APPLICABILITY

When specifically invoked by project work plans, sampling plans, or QA plans, this technical procedure shall apply to all types of air, soil, water, sediment, biological, and/or core samples collected in environmental investigations by Golder Associates Inc., and is applicable from the time of sample acquisition until custody of the sample is transferred to an analytical or geotechnical laboratory.

3. DEFINITIONS

3.1 Custody

Custody refers to the physical responsibility for sample integrity, handling, and/or transportation. Custody responsibilities are effectively met if the samples are:

- in the responsible individual's physical possession,
- in the responsible individual's visual range after having taken possession,
- secured by the responsible individual so that no tampering can occur, or
- secured or locked by the responsible individual in an area in which access is restricted to authorized personnel.

3.2 Chain of Custody

Chain of custody refers to the history of the physical transfer of samples between the Sampler, the transporter, or carrier, and the Laboratory Technician. Chain of custody documentation is required as evidence that the integrity of samples was maintained during transfer.

4. REFERENCES

4.1 EPA, 1986, NEIC Policies and Procedures; US Department of Ecology, National Enforcement Investigations Center, Denver, Colorado.

4.2 Golder Associates Technical Procedure TP-1.2-2, "Geotechnical Rock Core Logging."

5. DISCUSSION

Environmental samples must be tracked, handled and transported in a manner such that sample integrity and identification (to the location and interval at which they were obtained) is maintained. The Sample Custodian must maintain proper storage and custody of samples from the time of collection until transport to the laboratory. The Sampler shall initiate Chain of Custody forms which accompany samples from the collection site to the laboratory and provide documentation of any transfer of custody throughout transport. Sample identification and integrity shall be ensured the application of seals and labels to the sample containers at the time of sample collection. Seals and labels shall be verified upon receipt of samples at the analytical laboratory; unacceptable samples shall be identified on the Chain of Custody form, and referred to the Geologist/Field Engineer or Project Manager for evaluation and appropriate disposition.

6. RESPONSIBILITIES

6.1 Project Manager

The Project Manager is responsible for the overall management of sampling environmental activities, for designating the sample shipment method (considering permitted sample holding times), for delegating sampling responsibilities to qualified personnel, and reviewing any Field Change Requests that may be initiated during the investigation.

6.2 Geologist/Field Engineer

The Geologist/Field Engineer is responsible for: 1) general supervision of sampling operations as directed by the Project Manager; 2) ensuring proper temporary storage of samples, and proper transportation of samples from the sampling site to the laboratory; and 3) initiating Field Change Requests when required. The Geologist/Field Engineer is also responsible for tracking Chain of Custody forms for samples to ensure timely receipt of the completed original, for reviewing Chain of Custody forms to ensure appropriate documentation of sample transfers, and for advising the Project Manager of any problems observed that are related to sample integrity and chain of custody. The Geologist/Field Engineer may delegate document tracking and review responsibilities to suitably qualified personnel.

6.3 Sampler

The Sampler may be the same individual as the Geologist/Field Engineer and is responsible for: 1) sample acquisition in compliance with applicable procedures; 2) for checking sample integrity and documentation prior to transfer; 3) for initiating the Chain of Custody form; 4) for initial transfer of samples; and 5) for physically transferring the samples to the transporter (or directly to the laboratory).

6.4 Laboratory Sample Custodian

The Laboratory Sample Custodian (or designated sample receiving technician) is responsible for: 1) inspecting transferred samples to ensure that seals are intact, that labels are affixed, that sample condition is acceptable, and that Sample Integrity Data Sheets are available, when required for a particular project;, 2) for completion of the Chain of Custody form upon receipt and for forwarding copies of the completed Chain of Custody form to the Project Manager; and 3) for segregating and identifying unacceptable samples, and subsequent notification of the Project Manager.

6.5 Document Custodian

The Document Custodian is responsible for maintaining completed chain of custody records in the project files.

7. EQUIPMENT AND MATERIALS

- Seals and labels (Exhibit A)
- Sample Integrity Data Sheets (Exhibit B), if required by the applicable sampling procedure, work plan, sampling plan, or QA plan, or if requested by the Project Manager
- Chain of Custody forms (Exhibit C)
- Field Change Request form (Exhibit D)
- Packing and shipping materials, which may include coolers or insulated packing boxes, "blue ice" or dry ice, cardboard packing boxes, wooden core storage boxes, and shipping labels

8. PROCEDURE

8.1 Seals, Labels, and Initial Storage

At the time of collection, all samples shall be sealed, labeled, and appropriately stored in the custody of the sample custodian (as defined in 3.1 above). Examples of standard seals and labels are included in Exhibit A.

8.2 Sample Packaging

All samples shall be packaged appropriately for shipping to protect them from damage, to ensure that moisture content is maintained where necessary, and to ensure that appropriate temperatures are maintained as required. All sample shipping containers shall be sealed (see Exhibit A) to prevent tampering.

Environmental core sample boxing, marking, and labeling shall be in compliance with Section 8.3 of TP-1.2-2, "Geotechnical Rock Core Logging." Other types of environmental samples stored in jars or bottles may be packaged in insulated coolers, or, if sample temperature is not a concern, in the original sample container packing boxes. Where cooling is required, samples shall be shipped in insulated coolers containing "blue ice" packages sufficient to keep the samples at 4°C ± 2°.

Samples from boreholes shall be packaged as follows: beginning with the first sample taken, jars shall be placed in shipping containers from the top right corner downward, and from left to right as shown in Figure 8-1.

A label containing the following information shall be affixed to the front of each shipping container containing environmental samples:

- Project Number
- Location
- Borehole number (if appropriate)
- Date collected
- Sample numbers enclosed

Boxes shall be numbered consecutively; the last box from a borehole or drillhole shall also be identified "EOH," i.e, end of hole.

8.3 Sample Examination

Prior to transfer of samples, the Sampler shall ensure that:

- labels are affixed and completely filled out,
- seals are intact and completely filled out,
- special handling and storage requirements are identified where required,
- Sample Integrity Data Sheets (Exhibit B) are available where required by applicable sampling procedures or the Project Manager,
- there are no indications of sample container leaks or other questionable conditions that may affect the integrity of the sample, and that
- hazardous and/or radioactive samples are clearly identified as such.

Samples that do not meet the requirements for initial transfer shall be referred to the Geologist/Field Engineer for disposition.

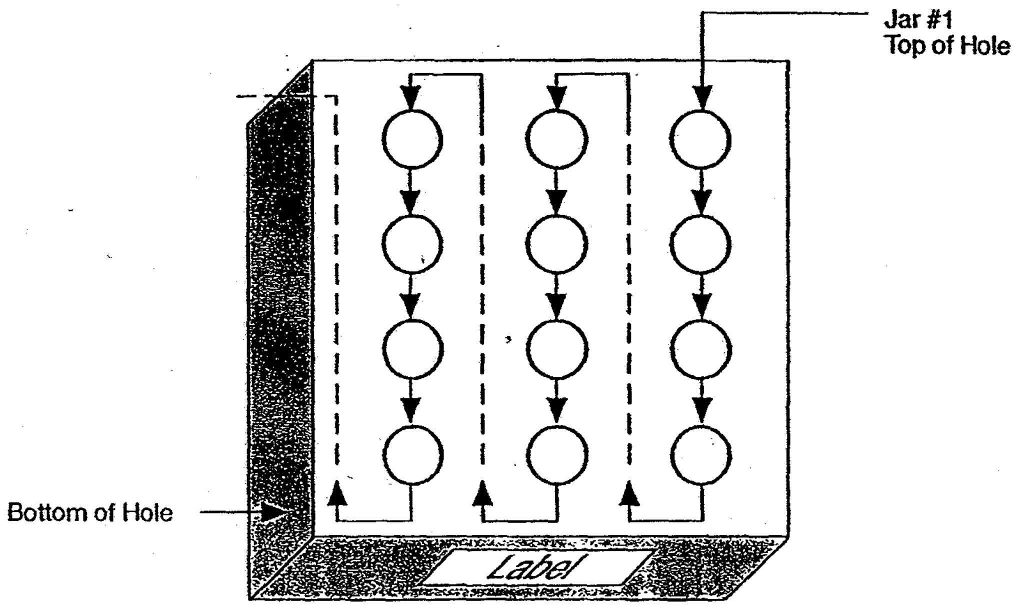


FIGURE **8-1**
SAMPLE CONTAINER PACKING ARRANGEMENT
TP-1.2-23

8.4 Chain of Custody Form Initiation

The Sampler shall initiate the Chain of Custody form (Exhibit C) for the initial transfer of samples. Chain of Custody forms supplied by the analytical laboratory may be used in lieu of the form shown in Exhibit C. The following information shall be entered on the form:

- the destination of the samples and the transporter or carrier,
- the date by which the laboratory should acknowledge receipt,
- the project identification and sampling site,
- the date and time of sample collection,
- the sample identification numbers and descriptions.

When all required information has been entered the Sampler shall sign the Chain of Custody form as the initiator.

8.5 Transfer of Custody

To document the initial transfer of samples, the Sampler relinquishing custody and the transporter accepting custody shall sign, date, and note the time of transfer on the Chain of Custody form. If the transporter is not an employee of Golder Associates Inc., the Sampler may identify the carrier and reference the bill of lading number in lieu of the transporter's signature. The Chain of Custody form is in triplicate. One copy of the Chain of Custody form shall be forwarded to the Geologist/Field Engineer by the Sampler. The original form and the remaining copy shall accompany the samples.

8.6 Receipt at Destination

The Laboratory Sample Custodian shall inspect the transferred samples to ensure that:

- the seals are intact
- the labels are affixed and legible
- Sample Integrity Data Sheets are available where required
- the physical condition of the samples is acceptable, and
- the samples being transferred directly correspond to those listed on the Chain of Custody form

If the integrity of the samples is questionable, the Laboratory Technician shall notify the Project Manager, segregate the unacceptable samples and identify them on the Chain of Custody Form. Otherwise, the Laboratory Sample Custodian and the transporter shall sign, date, and note the time of transfer on the Chain of Custody form. If the transporter is not an employee of Golder Associates Inc., the Laboratory Sample Custodian may identify the carrier and reference the bill of lading number in lieu of the transporter's signature. The Laboratory Sample Custodian shall retain the remaining copy of the Chain of Custody form and forward the original to the Geologist/Field Engineer. Appropriate laboratory custody procedures shall be initiated upon completion of transfer of custody in compliance with the laboratory's internal QA program requirements.

8.7 Document Tracking

The copy of the Chain of Custody form recording the initial transfer of samples shall be forwarded to the Geologist/Field Engineer, followed by the completed original. The Geologist/Field Engineer shall track the Chain of Custody form to ensure timely completion and receipt of the original, based on the laboratory acknowledgement due date indicated on the form.

After receipt of the completed original, the Geologist/Field Engineer may discard the copy. The completed original Chain of Custody form shall be forwarded to the project files. Chain of Custody forms determined to be overdue or incorrectly completed shall be referred to the Project Manager for appropriate action.

8.8 Field Change Request

Variation from established procedure requirements may be necessary due to unique circumstances encountered on individual projects. All variations from established procedures shall be documented on Field Change Request form (Exhibit D) and reviewed by the Project Manager and the QA Manager.

The Project Manager may authorize individual Geologist/Field Engineers to initiate necessary variations. If possible, the request for variation shall be reviewed by the Project Manager and the QA Manager prior to implementation. If prior review is not possible, the variation may be implemented immediately at the direction of the Geologist/Field Engineer, provided that the Project Manager is notified of the variation within 24 hours of the implementation, and the Field Change Request is forwarded to the Project Manager and QA Manager within 2 working days of implementation. If the variation is unacceptable to either reviewer, the activity shall be reperformed or action shall be taken as indicated in the Comments section of the reviewed Field Change Request. All completed Field Change Requests shall be maintained in project records.

Golder Associates

Location ____________________
Job No. ________ Date ____________
Boring No. _____ Sample No. _______
Depth ________ Blows ____________
Description ____________________
____
____
____
Driller ________ Engr. ____________

Golder Associates

Sample I.D. No.

Date ____________ Time ____________
Station ____________ Depth ____________
Media ____________________
Preservative ____________________
Sampled by ____________________

Golder Associates	Sent By: ____________
Seal Number 2455	Date: ____________
	Golder Associates

EXHIBIT **A**

SEALS AND LABELS

TP-1.2-23

SAMPLE INTEGRITY DATA SHEET

Plant/Site ______________________ Project No. ______________

Site Location ______________________ Sample ID ______________

Sampling Location ____

____

Technical Procedure Reference(s) ______________________________

Type of Sampler ____

Date ______________________ Time ______________________

Media ______________________ Station ______________________

Sample Type: grab time composite space composite

Sample Acquisition Measurements (depth, volume of static well water and purged water, etc.)

____

____

____

Sample Description ____

____

____

Field Measurements on Sample(pH, conductivity, etc.) ___________

____

____

____

Aliquot Amount	Container	Preservation/Amount

Sampler (signature) ______________________ Date ______________

Superviser (signature) ______________________ Date ______________

Golder Associates

EXHIBIT **B**

Sample Integrity Data Sheet

TP-1.2-23

PROJECT NO. IPE-1024 DRAWING NO. 67020 DATE 7/17/96 DRAWN BY DD

Golder Associates

CHAIN OF CUSTODY RECORD

PROJ. NO.	SITE/LOCATION
SAMPLERS: *(Signature)*	

STA. NO.	DATE	TIME	SAMPLE TYPE	MEDIA	SAMPLE IDENTIFICATION	NO. OF CON-TAINERS	AMOUNT/ PRESERVATIVE						SEAL NO.	SEAL INTACT ? (Y or N)	REMARKS (with initials)

Relinquished by: *(Signature/Firm)*	Date/Time	Received by: *(Signature/Firm)*	Relinquished by: *(Signature/Firm)*	Date/Time	Received by: *(Signature/Firm)*
Relinquished by: *(Signature/Firm)*	Date/Time	Received by: *(Signature/Firm)*	Relinquished by: *(Signature/Firm)*	Date/Time	Received by: *(Signature/Firm)*
Relinquished by: *(Signature/Firm)*	Date/Time	Received by: *(Signature/Firm)*	Date/Time	Remarks (attachments if necessary)	

EXHIBIT **C**

CHAIN OF CUSTODY FORM

TP-1.2-23

PROJECT NO. IP3 1024 DRAWING NO. 67019 DATE 7/17/96 DRAWN BY CB

Golder Associates

FIELD CHANGE REQUEST

Golder Associates

Job/Task Number: ______

Other Affected Documents: ______

Requested Change: ______

Reason for Change: ______

Change Requested by: ______ Date ______

Reviewed by: ______ Date ______
GAI Project Manager

Comments: ______

Reviewed by: ______ Date ______
GAI QA Manager

Comments: ______

Golder Associates Inc.

EXHIBIT D

FIELD CHANGE REQUEST FORM

TP-1.2-23

1. PURPOSE

This document describes the sampling protocols used by Golder Associates to collect surface water samples. It contains sampling instructions and information concerning appropriate containers, preservation, and handling of water quality samples.

2. APPLICABILITY

This technical procedure is applicable to any persons involved in the collection of surface water samples. It is applicable to all geographic areas.

3. DEFINITIONS

3.1 Analytical Request Form

Standard form provided by analytical laboratories. This form is filled out by the person collecting samples and is used to indicate how each sample is to be analyzed. This form is often combined with the Chain-of-Custody Form in a single document.

3.2 Chain-of-Custody Form

Standard form used to track the movement of sample containers from the time they leave the field until they arrive at the specified laboratory. The Chain-of-Custody form provides a clear record of sample transport and handling, thereby reducing the risk of sample loss during transport. This form may be combined with the Analytical Request Form in a single document.

3.3 Chemical Analysis

Analytical procedure used to measure the *amount* of a certain compound, or group of compounds, present in a sample.

3.4 Preservatives

Preservatives are used to maintain sample integrity from the time a sample is collected until it is analyzed. Sample preservation may involve adding acid or other fixatives to collected waters or simply keeping them refrigerated. Sample-specific requirements are outlined in this document (Table 1); preservatives, when required, are provided by the analytical laboratory.

3.5 Sample Bottles

Sample bottles are containers specifically designed and prepared for storing liquid samples. Sample bottle type, material, size, and type of lid are specific for particular groups of analytes. Sample bottles must be properly cleaned and prepared by a laboratory or the manufacturer. Table 1 summarizes bottle type and preparation requirements.

3.6 Surface Water Sample

A surface water sample is defined as water acquired from a surface water body for chemical analyses that is representative of surface water within the cross-section of a lake, stream, or river being sampled.

3.7 Quality Assurance/Quality Control (QA/QC)

Quality Assurance refers to a detailed protocol used to produce high quality products, while Quality Control refers to the process by which this protocol is tested to ensure that final products are of the specified quality. With reference to water sampling, QA protocol includes the use trained personnel, proper sampling methods, clean containers and equipment, proper sample preservation and transportation and detailed documentation of the entire process; field, travel and other assorted test blanks are used for Quality Control testing.

3.8 Sample Types

3.8.1 Grab Samples

Sample containing water collected during a single sampling event (i.e., water taken from a given place at a given time).

3.8.2 Composite Samples

Sample containing a mixture of water collected from multiple locations or from different times at the same location.

3.8.3 Equipment Blanks

Equipment blanks are used to detect contamination from sampling equipment. They are prepared by rinsing precleaned equipment with deionized water and collecting the rinsate into an appropriate container.

3.8.4 Field Blanks

Field blanks are used to detect contamination during sample collection and transport. They are prepared during a sampling event by filling the appropriate container with deionized water. Field blanks are usually used in situations where there is reason to suspect that contamination will occur during sample collection and transport.

3.8.5 Travel Blanks

Travel blanks detect sample contamination during transport. Travel blanks consist of pre-filled bottles provided by the analytical lab. They accompany empty sample bottles to the field site, where they are left intact and unopened inside the shipping cooler. The unopened travel blanks are then returned to the analytical lab to be analyzed along with collected samples.

3.8.6 Field Spikes

Field spikes are used to measure the performance of the complete analytical system, including sample handling, preservation and storage, as well as interference from the sample matrix. To generate a field spike, field personnel fill the usual sampling container with sample, leaving a small amount of space at the top. They then add a specified amount of the chemical or compound of interest to the bottle and submit it with the rest of the samples. In general, field spikes are not recommended due to the logistical difficulties of transporting concentrated solutions in the field. If there is reason to doubt the performance of the sampling system, then a separate study involving field spikes should be carried out.

3.8.7 Standard Reference Samples

Standard reference samples, or blind QA samples, are samples of known concentration that are submitted to the analytical lab as a normal sample. The lab is not informed about the identity of the sample until after all analyses are complete.

3.8.8 Replicate Samples

Replicate samples are used to evaluate within-site variation. Replicate samples are collected by filling multiple containers at a single site. They are labeled and preserved individually and are submitted separately to the analytical laboratory. Check the field sampling plan (FSP) for the number of replicate samples required per sampling site.

3.8.9 Split Samples

Split samples are used to check analytical variation. A single sample (e.g. grab) is collected and is split into two sample containers. These are labeled and preserved individually and are submitted separately to the analytical laboratory.

4. REFERENCES AND SUGGESTED READING

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Clesceri, L.S., A.E. Greenberg and R.R. Trussell. 1989. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, D.C.

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Golder Associates Inc. Technical Procedure TP-1.2-23, "Chain of Custody."

U.S. Department of the Interior, 1977, National Handbook of recommended methods for water-data acquisition, Reston, VA.

U.S. EPA, 1994, *U.S. EPA Contract Laboratory Program National Functional Guidelines for Inorganics Data Review*, EPA 540/R-94/013, U.S. EPA Office of Emergency and Remedial Response, Washington, D.C.

U.S. Geological Survey, 1982, Measurement and Computation of Streamflow: Volume 1 and 2. Washington, D.C.

U.S. EPA, 1986, *Test Methods for Evaluating Solid Waste - (SW-846)*, 3rd Edition (Final Update III, December 1996), U.S. EPA/Office of Solid Waste, Washington, D.C.

40 CFR 136, U.S. EPA, *Guidelines Establishing Test Procedures for the Analysis of Pollutants.* Title 40 Part 136 of the Code of Federal Regulations.

5. DISCUSSION

5.1 Sampling Procedures

Samples are collected as representative pieces of a larger puzzle. Ideally, they should describe all of the characteristics of the larger body from which they originate, which, by its very definition, is too large to analyze directly. As a result, it is very important to follow a well-organized sampling plan and to preserve sample integrity throughout the collection and transportation process.

5.1.1 General Practices

Usually, analytical laboratories will provide pre-cleaned sample containers, shipping containers, required forms for sample submission and specific sample shipping instructions. It is important to check with the lab that these arrangements have been made. Similarly, field crews should familiarize themselves with the FSP before initiating a sampling program. By reviewing the instructions, personnel can ensure that they have all of the equipment they require to fulfill the objectives of the sampling program. Field crews will also then be aware of the types of samples they are being asked to collect, be they grab samples, composite samples or QA/QC test blanks. Finally, sample crews should organize themselves such that samples will be collected and shipped during the early part of the work week to avoid delays caused by weekend shipping or make specific arrangements with laboratories to receive samples on the weekend.

Sampling Locations. General sampling locations are described in FSP. However, field crews will have a certain degree of freedom in choosing the exact locations from which to take the samples. When selecting these sites, personnel should consider the layout of the local environment, project objectives and personal safety. They should then choose areas that are both easily accessible and representative of the target waterbody or waterbodies.

Once sampling sites have been identified, they must be described relative to permanent landmarks, such as groundwater wells, outfalls or distinctive landscape features; measuring the distance from permanent landmarks to each site with an appropriate compass heading is recommended. Ideally, one should try to use the Global Positioning System (GPS), but locations can also be recorded as the perpendicular distance from the shoreline and the distance upstream or downstream of a permanent landmark.

Sample Collection. Where possible, start sampling at the least contaminated site (i.e., the reference site) and move from there to the more contaminated areas.

If sampling equipment must be used, then it must be cleaned before and after use. This may involve rinsing with ambient water, cleaning with soap and water, acid washing, rinsing with organic solvents or pure water, or a combination of these. Refer to the FSP for details.

Each sample bottle must be labeled at the time of collection with either waterproof, permanent marker or using pre-printed waterproof labels. See section 5.3.2 for details of label format.

When sampling, it is important to rinse sample containers 3 times before taking a sample. Rinse each bottle by partially filling it with ambient water, loosely attaching the cap and shaking the bottle; drain the water and repeat the process. As a general rule, rinse plastic bottles unless instructed otherwise by the analytical laboratory. Bottles that already contain the appropriate preservatives and containers for the following analyses should *not* be rinsed prior to taking the sample:

- volatile organic compounds (VOCs), including total volatile hydrocarbons (TVH),
- total extractable hydrocarbons (TEH),
- BTEX (benzene, toluene, ethylbenzene and xylene)
- total petroleum hydrocarbons (TPH; includes TVH, TEH and BTEX); and
- bacteriological testing (e.g., fecal coliforms).

Carefully fill sample containers, without splashing, leaving only enough space for preservatives (if required - see Table 1). Be sure to keep hands and fingers downstream of bottle opening and sample upstream of bridges, boats and yourself to prevent sample contamination. The samples will be collected in flowing water, unless otherwise specified in the FSP, from areas where the flow is well mixed. If no preservatives need to be added, completely fill the bottles and cap tightly. There should be as little air in the containers as possible, as it can affect sample integrity.

Whenever possible, fill sample containers directly from the source, without using an intermediate container to transfer the sample. This avoids potential sample contamination due to carry-over from one sample to the next. Also, take care to avoid contaminating sample waters through contact with rubber, oil, gasoline and other machinery fluids, metal-based paints, cigarette ash, paper tissues and other such material.

Sample bottles should then be stored appropriately (Table 1). In most cases, this will involve keeping the sample cool (4°C) and dark. Samples should never be allowed to freeze and should be shipped as soon as possible to the appropriate analytical lab, in coolers with reusable ice packs. Avoid using bags of ice purchased from convenience stores; the water that leaks out of these bags as the ice melts may ruin sample labels.

Chain-of-Custody and Analytical Request forms must accompany all samples (one set of forms per sample shipment). Prior to shipping, the person submitting the sample should inform the analytical lab by telephone, e-mail, or fax that the samples will be arriving. As well, he or she should check back later to confirm arrival of the samples and to explain analysis requests if needed.

5.1.2 Sampling for Metals

When collecting samples for a metals analysis, it is important that sample waters do not come into contact with any metal products. Samples for metals analysis also have other stringent collection and preservation requirements (Table 1). For example, waters collected for dissolved metal analysis have to be field-filtered using a 0.45 μm polycarbonate or cellulose acetate filter and then preserved with acid. Field-filtering should be conducted as soon as possible after sampling. If field-filtering is not possible, then acid preservatives should not be added and the laboratory should be notified to filter the sample as soon as possible after sample receipt.

Field crews need to be aware of these restrictions to ensure that samples are taken correctly and that they maintain their integrity until they can be analyzed. Special sampling and preservation instructions should be included in the FSP.

5.1.3 Sampling for Organic Chemicals

In addition to the general principles outlined above, there are specific protocols associated with sampling for organic measurements. As described above, sample bottles should *not* be rinsed prior to taking samples for certain organics analyses. It is also very important to completely fill each bottle, as certain organics will volatilize into the overlying air space and will be lost after opening the bottle. Finally, proper containers must be used when sampling for organics, since some bottles will release or absorb organic compounds when filled with water. Generally, glass containers are used, but certain tests may require other materials; be sure to obtain the appropriate sample bottles from the analytical laboratory and refer to the FSP.

5.2 Sample Documentation

Proper sample documentation is important because lack of careful documentation can lead to misunderstandings and questionable test results. Components of proper documentation of field activities are described below.

5.2.1 Field Notebooks

Field notebooks must be kept, describing all field activities. Format of field notes and information to be recorded should follow Golder Associates' specific guidelines. During the field survey, field notes must be maintained in a permanent, safe location at the field site where samples are collected. If possible, new entries in the field note book should be photocopied at the end of each field day and copies should be stored in a safe place.

5.2.2 Sample Labels

Sample labels must contain the following information:

- Sample identifier (name of site or sample code);
- Date (written as day/month/year; month abbreviated as three letters) and time (24 hour clock) of collection;
- Initials of collector; and
- Analysis requested (this is usually done by the analytical laboratory in the form of a code on the sample bottle).

Fill out labels at the time of collection using waterproof ink and affix a label to each sample container. Plastic bottles may be labeled by writing directly on the bottle using a waterproof marker; however, this approach is not recommended if samples are transported over long distances (friction may rub label off) or if bags of ice are used to keep the samples cool (water may damage label information).

5.2.3 Custody Seals

Numbered seals should be used (when required by the FSP) to detect tampering with samples in transit. Attach the seal in a way that it is necessary to break it to open the cooler containing the samples. The number on the custody seal should be recorded in the field note book and on the Chain-of-Custody and Analytical Request forms

5.2.4 Chain-of-Custody Forms and Analytical Request Forms

Chain-of-Custody and Analytical Request forms must accompany all samples submitted for analysis in accordance with procedure TP1.2-23, "Chain of Custody". These forms are usually combined as a single document. An example of Golder Associates' combined Chain-of-Custody and Analytical Request Form is provided in Exhibit 1.

The combined form must be filled out completely and the white and yellow copies should be sent along with the samples being submitted. Field personnel should retain the pink copy after it is signed by the shipper. Depending on the shipping container, these forms can either be enclosed inside the sealed container or attached firmly to the outside of the container. In either case, it is advisable to enclose the forms within a waterproof plastic bag to guard against damage. It is important that each person having custody or control of the samples identify themselves on this form. This means the person collecting the sample; intermediate persons involved in packaging, storing or transporting the sample; and the person accepting the sample on behalf of the analytical lab must all be identified.

5.3 Sample QA/QC

The main goal of sample QA/QC is to monitor for various sources of contamination during sample collection, transport and analysis. This process will involve the use of field, travel and other test blanks. QA/QC programs are designed on a project-specific basis. Details of individual QA/QC programs are described in the FSP.

6. EQUIPMENT AND MATERIALS

6.1 Sampling

The following is a list of sampling equipment generally recommended for surface water sampling:

- Pre-cleaned sample bottles and required preservatives (usually supplied by the analytical laboratory)
- Coolers and reusable ice packs
- Waterproof labels and permanent markers
- Sampling equipment (e.g. Kemmerer or Van Dorn bottles)

6.2 Site Location and Sample Documentation

For proper sample site identification and sample documentation, field crews may need:

- Bound, water-proof field logbooks
- Maps
- Air photos
- Indelible ink pens and pencils
- Long tape measure
- Survey flagging tape
- Compass
- GPS unit
- Combined Analytical Request and Chain-of-Custody forms

6.3 Health and Safety

The following health and safety equipment is recommended for surface water sampling:

- Waders and waterproof gloves
- Heavy socks, warm pants, rain gear and other articles of clothing suitable for prolonged water work
- Extra set of clothes
- First aid kit
- Approved personal floatation device for deep water or boat work

S:/groups/qa/tp3-1024/TP1_2-26.doc

TABLE 1

SAMPLE CONTAINER CODES, TYPES, VOLUMES, PREPARATION, SPECIAL HANDLING, PRESERVATION, HOLDING TIMES

Analysis	Cont. Code	Containers, Water	Handling and Preservation	Holding Time
Volatile Organics	V	2, 40ml glass vial teflon lined septum	Store 4±2°C; handle upwind from equip. Fumes, no headspace permitted; Pres with HCl to pH <2 for volatile aromatics	7 days 14 days (HCl pres.)
Base/Neutral and Acid Extractable Organics	SV	2, 1 liter amber glass, teflon lined cap	Store 4±2°C; handle upwind from equip. fumes; no contact with plastics, gloves	7 days until extraction 40 days thereafter
Organochlorine Pesticides and PCBs	P	2, 1 liter amber glass, teflon lined cap	Store 4±2°C; handle upwind from equip. fumes; no contact with plastics, gloves	7 days until extraction 40 days thereafter
Herbicides	H	2, 1 liter amber glass, teflon lined cap	Store 4±2°C; handle upwind from equip. fumes; no contact with plastic, gloves	7 days until extraction 40 days thereafter
Total Fuel Hydrocarbons (Fuel Fingerprint)	TH	1, 125 ml amber glass, teflon lined septum	Store 4±2°C; handle upwind from equip. fumes, no headspace permitted; pres with HCl to pH <2	14 days
Total Petroleum Hydrocarbons or Oil and Grease	OG	1, 1 liter glass, teflon lined cap	Store 4±2°C; handle upwind from equip. fumes, no contact with gloves or plastics; pres with HCl to pH <2	28 days
Cyanide (total)	CN	1,1 liter plastic	Store 4±2°C; pres with NaOH to pH >12	14 days
Sulfide (total)	S	1, 1 liter plastic	Store 4±2°C; pres with ZnOAC/NaOH to pH >12	7 days
Chloride, Sulfate, pH Conductivity and Total Dissolved Solids	MA	1,1 liter plastic	Store 4±2°C.	28 days (Chloride, sulfate and conductivity) Analyze on-site (pH) 7 days (TDS)

SAMPLE CONTAINER CODES, TYPES, VOLUMES, PREPARATION,
SPECIAL HANDLING, PRESERVATION, HOLDING TIMES,

Analysis	Cont. Code	Containers, Water	Handling and Preservation	Holding Time
Major Cations and Metals	TM	1,1 liter plastic	0.45 um filter, pres with HNO_3 to pH <2	6 months (28 days for mercury)
Gamma Emitting Radionuclides	GR	2, 1 liter plastic	0.45 um filter, pres with HNO_3 to pH <2	6 months (record exact date/time of sampling for calculation of half-life decay)
Alpha Emitting Radionuclides	AR	2, 1 liter plastic	0.45 um filter, pres with HNO_3 to pH <2	6 months (record exact date/time of sampling for calculation of half-life decay)
Beta Emitting Radionuclides	BR	2, 1 liter plastic	0.45 um filter, pres with HNO_3 to pH <2	6 months (record exact date/time of sampling for calculation of half-life decay)
Total Phosphorus, Ammonia-N, Nitrate/nitrite-N, COD and TOC	TP	1, 1 liter plastic	Store 4±2°C; pres with H_2SO_4 to pH <2; store in dark	28 days
Orthophosphate	OP	1, 1 liter plastic	0.45 um filter, store 4±2°C	48 hours

CHAIN OF CUSTODY RECORD

PROJ. NO.	SITE/LOCATION
SAMPLERS: *(Signature)*	

STA. NO.	DATE	TIME	SAMPLE TYPE	MEDIA	SAMPLE IDENTIFICATION	NO. OF CON-TAINERS	AMOUNT/ PRESERVATIVE						SEAL NO.	SEAL INTACT ? (Y or N)	REMARKS (with initials)

Relinquished by: *(Signature/Firm)*	Date/Time	Received by: *(Signature/Firm)*	Relinquished by: *(Signature/Firm)*	Date/Time	Received by: *(Signature/Firm)*
Relinquished by: *(Signature/Firm)*	Date/Time	Received by: *(Signature/Firm)*	Relinquished by: *(Signature/Firm)*	Date/Time	Received by: *(Signature/Firm)*
Relinquished by: *(Signature/Firm)*	Date/Time	Received by: *(Signature/Firm)*	Date/Time	Remarks (attachments if necessary)	

EXHIBIT 1

CHAIN OF CUSTODY FORM

DEPUE/SURFACE WATER/IL

PROJECT NO. 953 8222.3.3 DRAWING NO. 77288 DATE 3/23/98 DRAWN BY EA

Golder Associates

TP-1.3-1

Rev. 2

RECORD OF REVISION

Section	Description of Revision
All	New format throughout
1.	Editorial changes
7.	Added introduction sentence
8.2	Editorial changes to first sentence Deleted reference to TP-1.1-2, "Vertical and Horizontal Geodetic Survey"
8.3	Changed excavation depth to 4 feet
8.9 & Exhibit C	Added section and form for Field Change Requests

1. PURPOSE

This Technical Procedure establishes uniform methods of observation, identification, and recording of data observed in vertical excavations completed for the investigation of soils.

2. APPLICABILITY

This Technical Procedure is applicable to persons or parties engaged in the mapping of vertical shafts or test pits for soils investigations.

3. DEFINITIONS

3.1 Vertical Shaft

A supported excavation advanced in a vertical orientation, the purpose of which is to penetrate, examine, and test foundation soils in situ.

3.2 Test Pit

A supported or non-supported depth dependent excavation, the purpose of which is to penetrate, examine, sample and test surficial soils in situ.

3.3 Test Pit Mapping

Mapping accomplished by observing, identifying, and recording geologic information exposed in the walls of excavated test pits.

4. REFERENCES

4.1 Golder Associates Technical Procedure TP-1.2-6, "Field Identification of Soil."

5. DISCUSSION

5.1 None

6. RESPONSIBILITY

6.1 Geologist/Field Engineer

Responsible for completing the assigned mapping investigation.

6.2 Task Leader

Responsible for making periodic observations to determine effective and correct implementation of the shaft/test pit mapping program.

7. EQUIPMENT AND MATERIAL

Supplies required for Golder Associates field personnel generally include the following:

- Brunton compass, 0^0 to 360^0 divisions
- Base/site map and map board
- 35mm camera and film
- Field notebook or appropriate Field Report Forms (Exhibit A)
- Assorted standard field equipment (i.e., rock hammer, scales, wood stake markers, etc.)
- Measuring tape
- Engineers rule (6-feet long, with 0.10-foot graduations)
- Field Test Pit Log Forms (Exhibit B)
- Other equipment or material necessary to complete a specific task as determined by the task leader.
- Indelible ink pens.

8. PROCEDURE

8.1 General Considerations

Mapping activities shall be thorough, accurate, and shall follow sound engineering and geologic practice.

8.2 Location Mapping

Location mapping shall be to the level required and in accordance with accepted engineering and geologic practice. If the base map is of sufficient accuracy, the test pit location may be approximated within a 10' radius and physically identified by a wood stake marker. If the base map does not have the required accuracy, locations shall be described by either (1) tape measurement from three permanent features identifiable on the base map; (2) measured along a compass bearing from a permanent feature; or (3) triangulated with compass bearings from three permanent features identifiable on the base map. Compasses may be used only when the site does not contain magnetic or large metal objects. The locations so derived will be identified by a wood stake marker with test pit designation.

8.3 Test Pit Mapping

Test pit mapping shall be accomplished by the Golder Geologist/Engineer when the test pit has been advanced to a safe depth as determined by the Golder geologist/engineer or the maximum test pit depth. The Golder geologist/engineer shall not enter an excavation that is deeper than 4 feet unless (1) the sidewalls of the excavation are supported, or (2) the sidewalls have been appropriately sloped or benched.

8.4 Field Test Pit Log

The test pit stratigraphy, depth (measure from ground surface) of each strata, pit orientation, discernible structure and moisture (if discernible) will be recorded by the Golder geologist/engineer on the Field Test Pit Log (See Exhibit B). Any other observed data on the nature of the material present in the sidewalls of the excavation, such as cementation, contamination, fill debris, etc. will also be recorded on the Field Test Pit Log.

8.5 Structural Data

Structural data shall be recorded by azimuth to true north or by quadrants.

8.6 Photographic Record

35-mm color slides shall be taken of each test pit and important structural or stratigraphic features. A suitable reference object shall be placed in the field of view for scale. Photographs shall be described in the field notebook or appropriate Field Report Form and referenced on the Field Test Pit Log by the film roll number, and exposure number.

8.7 Field Reports

Field reports shall be produced in triplicate and the originals forwarded on a daily basis to the Project Document Custodian.

8.8 Test Pit Abandonment

All excavated materials shall be backfilled into the test pit and compacted with the backhoe bucket to an acceptably safe level as determined by the Golder Geologist/Engineer. The approximate center of the backfilled pit will be marked with a wood stake with test pit designation if further ground control will be required.

8.9 Field Change Request

Variation from established procedure requirements may be necessary due to unique circumstances encountered on individual projects. All variations from established procedures shall be documented on Field Change Request (Exhibit C) and reviewed by the Project Manager and the QA Manager.

The Project Manager may authorize individual Geologist/Engineers to initiate variations as necessary. If practical, the request for variation shall be reviewed by the Project Manager and the QA Manager prior to implementation. If prior review is not possible, the variation may be implemented immediately at the direction of the Geologist/Engineers, provided that the Project Manager is notified of the variation within 24 hours of implementation, and the Field Change Request is forwarded to the Project Manager and QA Manager for review within 2 working days of implementation. If the variation is unacceptable to either reviewer, the activity shall be reperformed or action shall be taken as indicated in the Comments section of the Field Change Request form.

All completed Field Change Request forms shall be maintained in project records.

s:\qa\tp3-1024\1129tt1.tp

GOLDER ASSOCIATES
4104 148th Avenue NE
Redmond, Washington 98052

(206) 883-0777

DATE	JOB NO.
PROJECT	
LOCATION	
CONTRACTOR	OWNER
WEATHER	TEMP. °at AM °at PM
PRESENT AT SITE	

TO ______________________

____

____

THE FOLLOWING WAS NOTED:

COPIES TO ______________________

____

FIELD REPORT

SIGNED ______________________

EXHIBIT **A**
FIELD REPORT
TP-1.3-1

Golder Associates

FIELD TEST PIT LOG

Temp. ________ Weather ________________ Engineer ____________ Operator ________ Test Pit ________

Equipment ________________ Contractor ________________ Date ________

Location ________________ Elevation ____________ Datum ________ Job ________

W ← 0 5 10 15 20 → E

0
5
10
15
20

EXAMPLE

Samples	
No	Depth

Sample Descriptions and Excavation Notes	Time	Depth of Hole	Depth to W/L

Special Notes

EXHIBIT B
FIELD TEST PIT LOG
TP-1.3-1

PROJECT NO. IP3 1024 DRAWING NO. 63275 DATE 12/8/95 DRAWN BY EA

FIELD CHANGE REQUEST

Golder Associates

Job/Task Number: ____________________

Other Affected Documents: ____________________

Requested Change: ____________________

Reason for Change: ____________________

Change Requested by: ____________________ Date ____________

Reviewed by: ____________________ Date ____________
GAI Project Manager

Comments: ____________________

Reviewed by: ____________________ Date ____________
GAI QA Manager

Comments: ____________________

EXHIBIT C
FIELD CHANGE
REQUEST FORM
TP-1.3-1

Record of Revisions

TP-1.4-6a
Revision -4-

Section	Description of Change
All	Rewritten. TP-1.4.6 has been split into two procedures, TP-1.4-6a for manual methods and TP-1.4-6b for automated methods.

1. PURPOSE

1.1 This technical procedure is to be used to establish a uniform procedure for measuring groundwater levels in borings, drill holes, monitoring wells, and piezometers, by manual methods using an electric water-level sounder.

1.2 An alternate technical procedure (TP-1.4-6b, "Automated Groundwater Level Measurement") is to be used in conjunction with this procedure when making automatic water-level measurements using a pressure transducer and datalogger system.

2. APPLICABILITY

2.1 This technical procedure is applicable to all personnel measuring water levels in wells manually using a calibrated electric water-level sounder. It is not applicable to the measurement of water levels in flowing (Artesian) wells, unless sufficient additional casing is added to prevent the flowing conditions.

2.2 This procedure is not applicable for the measurement of water levels by other methods, such as wetted tape, air line or pressure transducer.

3. DEFINITIONS

3.1 Electric Water Level Sounder

An instrument for manually measuring water levels in wells or boreholes. Electric water-level sounders are available in a variety of different types, but each works in essentially the same way: an open circuit involving an ammeter, bulb, and/or audible beeper and battery mounted within a reel of insulated two-wire electric cable. At the end of the two-wire cable is a weighted metal probe containing a partly shielded electrode. The cable is graduated or marked to indicate the length of cable above the tip of the electrode in the probe. The circuit is closed when the exposed electrode in the probe is immersed in water. Current flow is registered on the meter, illumination of the bulb, or sounding of the beeper on the reel. Some sounders also have a sensitivity adjustment.

3.2 Well or Borehole

For the purpose of this procedure, any hole in the ground (cased or open) that may contain groundwater, e.g., a boring, borehole, drill hole, test pit, water well, monitoring well, observation well, pumping well, or standpipe piezometer.

3.3 Measuring Point (MP)

A reference or datum established to provide a consistent point from which the water level is measured, -- usually a mark on the casing at the top of a well or borehole. The elevation of the measuring point should be established by surveying (differential leveling) from a bench mark of known elevation above the local or national vertical datum. The elevation of the measuring point should be established to an accuracy of 0.01 ft or better. Use of the ground surface as a measuring point is acceptable for measuring water levels in wells and boreholes during drilling, and in other situations (e.g., test pits) where no other stable reference point is available.

3.4 Diptube

A small-diameter (1- to 2-inch) tube (usually PVC) with slots over the lower 1 or 2 ft that is placed in a pumping well to provide a stilling effect that counteracts turbulence.

3.5 Pressure Transducer

A piece of electronic equipment used for measuring pressure (see TP-1.4-6b).

3.6 Datalogger

An electronic unit designed to collect and store data from a pressure transducer (see TP-1.4-6b).

3.7 Wetted Tape

Use of chalk on a measuring tape to sound the depth of water in a well. (This method is no longer in common use.)

4. REFERENCES

4.1 Cooley, R.L., et al., 1972. Hydrologic Engineering Methods for Water Resource Development, Vol. 10-Principles of Groundwater Hydrology, Section 6.01, U.S. Army Corps of Engineers (HEC-IHD-1000).

4.2 US Geological Survey, 1977. National Handbook of Recommended Methods for Water-Data Acquisition. Chapter 2 - Ground Water (Section 2.A), Office of Water Data Coordination, Washington DC.

4.3 Driscoll, F.G., 1986. Groundwater and Wells. (2nd Edition) Johnson Filtration Systems Inc., St. Paul, Minnesota.

4.4 American Society for Testing and Materials, 1987. Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well). (ASTM D 4750 - 87).

4.5 Golder Technical Procedure TP-1.4-6b, "Automated Groundwater Level Measurement".

5. DISCUSSION

5.1 Accuracy, Precision and Repeatability

The prime objectives in measuring a groundwater level are to obtain the depth to groundwater below a measuring point of known elevation, at a specific time and in a manner that is both precise, accurate and repeatable (if the water level is static). Measurement precision of 0.01 ft is achievable with the fully graduated tapes available on modern electric water-level sounders. However, practical difficulties of calibrating long sounder tapes, and their sensitivity to stretching, reduce the accuracy of readings to, at best, 0.05 ft. This is usually adequate for all practical purposes. Also, if no fixed measuring point is available, and the measurement is made in relation to the ground surface, this degree of accuracy and precision is not practical. Measurements made to ground surface should be recorded to the nearest 0.5 or 1.0 ft, and this should be noted in the water-level record.

5.2 Measurements in Pumping Wells

Turbulence caused by pumping can make measurements of dynamic water levels in difficult in wells that are being pumped. In this situation, a small-diameter diptube can be used to act as a stilling well. Measurements should be made inside the tube, provided it is long enough for the end of the tube to be submerged by at least 5 ft. If the top of the diptube is higher than the measuring point, this may be used as an alternate measuring point, but the difference must be recorded in the field notebook and on the Water Level Reading Forms (Exhibit A).

5.3 Potential Sources of Error

Be aware of the potential sources of error that can affect water-level measurements:

- Dirt, scum, oil, or floating product on the water surface can affect closure of the electric circuit in the water-level probe.
- Cascading water, leaking casing, or excessive condensation in the wellbore can cause the water-level probe to signal contact with water before the probe encounters the static water level in the well. This effect may be overcome using the sensitivity adjustment (if available).
- Changes in air pressure can cause small fluctuations in the water level.
- The water-level probe will not produce a signal if the battery is flat, if the switch on the reel is in the "Off" position, or if the sensitivity adjustment is set too low.
- In very deep wells (i.e., over 500 ft), the measurement of the water levels may be affected by non-verticality of the well, and by stretching of the electrical sounder tape.
- It is all too easy to mis-read the calibrated tape. Check each reading again immediately after noting it down.

5.4 Care of the Equipment

The electric water-level sounder is an expensive piece of equipment that should be treated with care:

- Avoid situations where the probe may become caught or stuck down-hole, for example, near casing centralizers or pump riser columns.
- Exercise control over the tape as it unwinds, especially into deep and/or uncased holes.
- Avoid abrasion of the electric tape against the lip of the casing: this causes excessive wear and eventual failure of the electric wires inside the tape.
- Rewind the tape evenly with markings visible, and avoid twisting or pulling on the tape.
- Replace the probe in its protective sleeve (if available) after cleaning.

6. RESPONSIBILITY

6.1 Field Engineer/Geologist/Hydrogeologist/Technician

Responsible for making and recording measurements in compliance with this technical procedure.

6.2 Task Leader

Responsible for:

- Direct supervision of personnel taking the measurements
- Designation of measuring points on wells or boreholes
- Determination of the maximum cable length required for the electric water-level sounder
- Guidance on the purpose, number, timing, and/or frequency of water-level measurements required
- Assurance that equipment and materials are available to permit accomplishment of the task

6.3 Equipment Manager

Responsible for:

- Maintenance of the electric water-level sounder in full working order
- Replacement or repair of damaged tape, probe, or other malfunctioning parts of the sounder
- Periodic calibration of the sounder tape to ensure markings are correct
- Procuring, checking, calibrating, and returning any water-level sounder obtained by rental.

7. EQUIPMENT AND MATERIAL

7.1 Electric water-level sounder with integral cable of sufficient length for the well(s) being measured .

7.2 Field notebook and/or appropriate Water Level Reading forms (Exhibit A).

7.3 Data on well locations, identification number, depth, measuring point description and elevation above survey datum, and previous or most recent water-level measurements (if available).

7.4 Decontamination solution and distilled/deionized rinse water .

7.5 Indelible ink pens.

7.6 Spare battery for electric water-level sounder.

8. PROCEDURE

8.1 Each water level probe or measuring tape used for recording water levels shall have the depth graduations calibrated by the Equipment Manager. Confirm that calibration is current by checking the "next due" date on the calibration sticker located on the equipment.

8.2 Record project number, project name, location, and state.

8.3 At each well, record date, time, well identification number, measuring point description (e.g., top of PVC casing), measuring device type, manufacturer and serial number and Golder equipment identification number.

8.4 Clean all downhole instruments and equipment before and after measurements between wells. Cleaning shall be with a non-phosphate detergent rinse followed by a rinse with approved tap water, then rinse with organic-free distilled/deionized water.

8.5 At least once at each well: measure and record the approximate distance from ground level to the measuring point. Measure the vertical distance from the top of casing, standpipe, monument, or other relevant points of reference to the measuring point, as appropriate.

8.6 Turn on the electric water-level sounder, check the battery using the test switch or button, lower the probe into the well and stop at the depth where the bulb or audible beeper indicates a completed circuit. Raise and lower the water-level sounder a small distance to break and remake the circuit, confirming that the water level can be repeatedly identified, and carefully establish the point at which the sounder circuit just closes. Record the length of the tape below the measuring point by reading the value indicated on the tape directly level with the measuring point, to the nearest 0.01 ft.

8.7 Enter date, time, well designation, measuring device and all measurements in a field notebook, or directly on a Water Level Readings Form (Exhibit A). The personnel making the measurement shall initial or sign each measurement recorded, and make any additional comments pertinent to the data collected.

8.8 If a field notebook is used, water-level measurements must be meticulously transferred to Water Level Readings Form (Exhibit A) at the earliest convenient time. All water level measurement records shall be maintained in the project records files.

8.9 Water-level measurements should be tabulated in a spreadsheet or entered into an electronic database file for project use. The spreadsheet or database should facilitate the calculation of water levels as elevations related to the appropriate survey datum. New water levels should be reviewed for consistency with previous measurements from the same location (for example, by plotting a hydrograph). Significant deviations that lack a clear physical cause (e.g., seasonal recharge, influence of pumping, borehole construction changes, use of packers or slug tests, barometric influences, etc.) should be investigated. If necessary, spurious water-level measurements should be retaken, and erroneous values annotated in the data record.

RECORD OF WATER LEVEL READINGS

Job. No. ______________ Project Name ______________ Location ______________

Bore-Hole No.	Date	Time	Measuring Device/ Serial No.	Measurement Point (M.P.)	Water Level below M.P.	Correction to Survey Mark	Survey Mark Elevation	Water Level Elevation	By	Comments

RECORD OF REVISIONS

TP-2.2-12
Revision -1-

Complete procedure revision. Procedure was updated to reflect actual practices in accordance with CAR 94-29.

1. PURPOSE

This technical procedure is to be used to manage analytical data received and processed by personnel assigned the responsibility of data management, data verification and data validation. This procedure details how analytical data in written and electronic format is to be handled, processed and maintained to facilitate incorporation into reports, for numerical evaluation and processing, transmittal to clients and incorporation into project specific database management systems.

2. APPLICABILITY

This technical procedure is applicable when required by project-specific planning documents, or at the direction of the Project Manager, to all Golder Associates Inc. (Golder) personnel and assigned subcontractors for the computerized management of analytical data. The procedures outlined herein are intended to be guidance for the use of a variety of computer-based data management systems.

3. DEFINITIONS

3.1 Analytical Data Management

Analytical data management is the process of receiving and processing analytical data results both in written and electronic format to provide data users with summary information about the data. Summary information may include tabular presentation of the data, summary and trend information about the data and status reports about the data.

3.2 Data User

Data users are the Project and Task Managers responsible for the review and evaluation of analytical data contained in any project-specific analytical data management system.

4. REFERENCES

Golder Associates Inc. Procedure QP-9.1, "Specific Work Instructions"

5. DISCUSSION

Analytical data shall be organized, entered into a database, verified for accuracy, and corrected as necessary. The database shall be updated to include validation results, and all updates shall be documented. Data management activities shall be assigned by Specific Work Instructions (SWIs) in accordance with procedure QP-9.1, "Specific Work Instructions." SWIs shall include references to client-specified validation procedures as applicable. Summary results and updated data reports shall be transmitted to data users at their request. Records associated with the implementation of this procedure shall be managed in accordance with the requirements of the governing Quality Assurance Project

Plan (QAPjP) or Quality Assurance Program Plan (QAPP) or as directed by the Project Manager.

6. RESPONSIBILITIES

6.1 Project Manager

The Golder Project Manager has overall responsibility for coordinating data management activities in compliance with this procedure; for assigning data management activities to properly qualified and trained personnel; for coordinating any corrective action issues with any supporting analytical laboratory or organization providing analytical data and for ensuring that processed analytical data records, reports and supporting documentation are routed to the project QA records system for retention as directed by governing QA program and/or project plans, or the Project Manager.

6.2 Data Manager

The Golder Data Manager is responsible for assignment of task responsibilities to Data Management Specialists under the direction of the Project Manager. The Data Manager shall be responsible for construction and modification of all computer based data management files and for ensuring that said files meet project specific technical and QA requirements as directed by governing QA program and/or project plans, or the Project Manager. The Data Manager shall be responsible for documenting the results of all data management activities, resolving questions, data gaps or errors with analytical data through coordination with the Project Manager and project QA representatives.

6.3 Data Management Specialist

Data Management Specialist (DMS) is responsible for performing all data management activities under the direction of the Data Manager; for processing electronic and hardcopy media in accordance with this procedure and for documenting all processing, checking, updates and corrections to all analytical data.

7. EQUIPMENT AND MATERIALS

Materials and equipment necessary to complete the activities addressed by this procedure include:

- copies of applicable forms from the analytical data packages for processing and any special instructions from the Data Manager or Project Manager with regards to the analytical data.

- lists of the appropriate acronyms and abbreviations of terms to be used in processing the data, entering and updating any database used for processing.

- copies of applicable data processing forms included as attachments to this procedure.

- computer with database software capability and software instruction reference manuals as applicable to the data management requirements.

- office space and office supplies for performance of data management activities.

- sufficient number of properly formatted electronic diskettes for making backup copies of all electronic files generated as part of this procedure for data security and integrity.

8. PROCEDURE

8.1 General Requirements

The Project Manager shall assign a Data Manager for the project. The Data Manager shall, with the concurrence of the Project Manager, assign Data Management Specialists (DMSs) as appropriate for the activities. All work assignments shall be made by SWI in accordance with procedure QP-9.1, "Specific Work Instructions." SWIs shall include reference to applicable portions of client-specified procedures as appropriate. The Data Manager shall provide the DMS with the current copies of applicable project specific data management plans, QAPP/QAPjP, laboratory statements of work, laboratory QAPjPs, work plan analyte lists, analyte detection limit goals and software reference manuals and shall specify the analytes of interest, reference analytical methods, contract required quantitation limits (CRQLs), and contract required detection limits (CRDLs).

The DMS shall complete several tasks on each batch of analytical data or sample delivery group (SDG) or data package. [Note: a SDG shall be defined as a group of samples (usually 20 or fewer) reported within the same laboratory data package]. These tasks are summarized in Sections 8.1.1 and 8.1.2 below. If a backup procedure is not otherwise in effect through network systems a disk backup of each database shall be prepared each day of entry or update.

8.1.1 Data Processing in Support of Environmental Assessment

8.1.1.1 Processing of Hardcopy Analytical Data in Support of Environmental Assessment

The following processing steps shall be completed by the Data Manager or their designee.

- Receive the Data and Assign Batch Identification - Receive the analytical results. Organize and review the analytical results to determine analytical fractions. Batch the result forms and attach a batch tag as provided in Attachment 1, with identifying information completed, and enter the batch into the batch log as provided in Attachment 2.

The following processing steps shall be completed by the Data Management Specialist:

- Construct Database Files - Construct sample, results, and compound database files according to the project requirements. (See Attachment 3 for a suggested format.)
- Enter Data - Enter results and qualifiers into the result database file from the batch of result forms. Enter sample number, sample date, sample location, and additional information, as required for the project, into the sample database file.
- Verify and Inventory - Upon completion of data entry, verify the entries, and complete and initial the batch tag. Forward the batch tag along with an inventory listing of the samples and analytical fractions in the batch to the project file.
- Incorporate - After any required corrections are made, incorporate new records into the database.
- Maintain Files - Maintain a copy of the batch tag and the associated hard copy data for DMS use.

8.1.1.2 Processing of Electronic Analytical Data in Support of Environmental Assessment

The following processing steps shall be completed by the Data Manager or their designee.

- Receive the Data and Assign Batch Identification - Receive electronic disks. Determine fractions contained in files. Attach a batch tag (see Attachment 1) containing identifying information to the disks. Log the batch (see Attachment 2), and submit a copy of the disks (marked with the batch number from the batch tag) and an inventory listing of the files contained on the disks to the project file.

The following steps shall be completed by the Data Management Specialist.

- Construct Database Files - Construct sample, results, and compound database files according to the project requirements. (See Attachment 3 for a suggested format.)
- Convert, Incorporate, and Enter Data - Convert electronic files into database software-compatible format. Incorporate converted data into the database. Enter sample number, sample date, sample location, and additional information, as required for the project, into the sample database file.
- Inventory - Complete and initial the batch tag. Forward the batch tag along with an inventory listing of the samples and analytical fractions in the batch to the project file.
- Maintain Files - Maintain a copy of the batch tag, the inventory listing, and the associated disk for DMS use.

8.1.1.3 Modification of Data in Support of Environmental Assessment

All modifications of data must be documented by submitting a listing of the pre- and post-change records to the project file. The DMS shall also maintain a copy of the listings.

8.1.2 Data Processing in Support of Data Validation

8.1.2.1 Processing of Analytical Data in Support of Data Validation

The following steps shall be taken by the Project Manager or their designee.

- Log and Copy - Log in a personal log, or otherwise track each package for status purposes. Copy the sample results forms, chain-of-custody forms, and case narratives. (Make two copies of the results forms, one for data entry, one for validation.)

- Organize and Review - Organize and review the analytical results to determine the type, analytical fractions, and analyses performed.

The following steps shall be completed by the Data Manager or Data Management Specialist.

- Construct the Database - Construct sample, results, and compound database files according to the format provided in Attachment 3.

- Enter Data - Enter the sample number, form type, form #, lab ID, results, qualifiers, error, MDA, and units into the result database file from the result forms. Enter the sample number, project name, sample date, sample location, data package number, and analytical fraction into the sample database file.

- Log and Verify - Enter the data package number, analytical fraction, and entry date for the sample results into the Data Processing Log provided in Attachment 4, and initial. Verify the entries, and initial the log.

- Modify Data - Based on copies of the modified results forms for the validated data, modify qualifiers in the results database, along with other editorial items as noted on the results forms by the data validator.

- Log and Generate Report - Enter the data package number, the date of modification, and initials into the Data Processing Log (Attachment 4). Generate the data package summary report as shown in Attachment 5, verify the entries, and forward it to the data validator.

8.2 Records Management

Within the context of governing QAPjP or QAPP requirements or as directed by the Project Manager, the DMS(s) shall comply with all records management and document control program requirements to protect all records associated with implementation of this procedure.

8.3 Documentation Requirements

Processing Forms, Logs and Update Forms (see Attachments) shall be completed and attached to the appropriate records for routing to the project files as data management tasks are completed.

8.4 Data Summary Reports

Tabular data summary reports to be included in validation reports shall be routed to the project files as required by governing QAPjP or QAPP, or as directed by the Project Manager.

ATTACHMENT 1

BATCH TAG

PROJECT NUMBER:		DATE:
DATA MANAGEMENT SPECIALIST:		
BATCH NUMBER [FROM BATCH LOG]:		
ELECTRONIC MEDIA		HARDCOPY MEDIA
SOFTWARE:	CLP:	ENTERED (FILENAME):
		VERIFIED:
		CORRECTED:
CONVERTED:		INVENTORIED:
FILENAME:		INCORPORATED:
INCORPORATED:		
INVENTORIED:		
COMMENTS:		

ATTACHMENT 2

BATCH LOG

BATCH #	DATE RECEIVED	FILENAME	DATA TYPE	MEDIA

ATTACHMENT 3

DATABASE FILE FORMATS

FIELD NAME	VALID VALUES	COLUMN	TYPE (SIZE)
DATABASE FILE FORMAT - RESULTS TABLE			
Sample Number	Client or Golder field sample identification number	1 - 12	CHAR(12)
Form Type	CLP, LAS, NCLP	13 - 16	CHAR(4)
Form Number	1A, 1B, 1C, 1D, 1E, 1F, I, NA, R, C	17 - 19	CHAR(3)
Lab Code	Client or Golder Lab Code	20 - 25	CHAR(6)
Constituent ID	Client-specific, CAS numbers, Element symbol and isotope or approved abbreviation	26 - 35	CHAR(10)
Media	BI - biota GW - groundwater SS - surface soil GS - geologic soil SW - surface water AT - air toxics SG - soil gas SL - sludge SE - sediment	36 - 38	CHAR(3)
Value Reported	The result associated with the analysis	39 - 51	NUMBER(13.3)
Concentration Flag	CLP Inorganic form I flag (B, J, R, U, UJ)	52 - 53	CHAR(2)

FIELD NAME	VALID VALUES	COLUMN	TYPE (SIZE)
DATABASE FILE FORMAT - RESULTS TABLE			
Qualifier	The validated result qualifier from the qualifier table, annotated form 1, Q qualifier form CLP organic forms or laboratory forms.	54 - 61	CHAR(8)
Counting Error	A measure of the error in the value reported resulting from equipment variability.	62 - 71	NUMBER(10.3)
MDA	Minimum detectable amount from radio-chemistry results	72 - 81	NUMBER(10.3)
Analysis Units	The reporting units in which the result was originally reported.	82 - 86	CHAR(5)
Changed	Field used for flagging whether record has been changed or not from the original unvalidated Form 1's, valid values are Y for yes, N for no	77 - 78	CHAR(2)

FIELD NAME	VALID VALUES	COLUMN	TYPE (SIZE)
DATABASE FILE FORMAT - SAMPLES TABLE			
Sample Number	Client or Golder field sample identification number	1 - 12	CHAR(12)

FIELD NAME	VALID VALUES	COLUMN	TYPE (SIZE)
DATABASE FILE FORMAT - SAMPLES TABLE			
Data Package ID, Batch or SDG	Client data package ID, data processing batch or laboratory SDG	13 - 32	CHAR(20)
Sample date	Sample collection date	33 - 40	CHAR(8) or DATE format
Location	Sample location or where the sample was collected, sample depth	41 - 55	CHAR(15)
Date package received	Date when data package received from Client or laboratory	56 - 63	CHAR(8) or DATE format
Date validation started	Date when data validation was started on the data package	64 - 71	CHAR(8) or date format
Date validation completed	Date when data validation was completed	72 - 79	CHAR(8) or date format
Date validation report completed	Date when validation report completed and transmitted	80 - 87	CHAR(8) or date format
Comments	Comments concerning the sample or sample type	88 - 127	CHAR(40)

FIELD NAME	VALID VALUES	COLUMN	TYPE(SIZE)
DATABASE FILE FORM - CONSTITUENTS TABLE			
Constituent ID	Client-specific, CAS number, element symbol, element symbol and isotope, approved abbreviation	1 - 10	CHAR(10)
Constituent Name	Client-specific, descriptive name associated with the constituent ID	11 - 50	CHAR(40)
Form Number	1A, 1B, 1C, 1D, 1E, 1F, I, NA, R, C	51 - 53	CHAR(3)
Order	Order in which results appear on the hard-copy form. Used for preparing summary reports.	54 - 60	NUMBER(7)

ATTACHMENT 4

DATA PROCESSING LOG

DATA PROCESSING LOG

DATA PKG ID	PROJECT	DATE ENTERED	FILENAME	DATA TYPE	MEDIA	INITIALS VERIFIED	DATE CORRECTED	INITIALS VERIFIED	COMMENTS

Golder Associates Inc.

ATTACHMENT 5

EXAMPLE DATA SUMMARY REPORT

Validated Data Summary, Data Package: W0351-QES

	Samp#	BODHM9		BODHN0		BODHN1		BODHN2		BODHN7		BODHN8	
	Date	12-27-94		12-27-94		12-27-94		12-27-94		12-27-94		12-27-94	
	Location	699-96-43		699-96-43		699-97-43		699-97-43		699-97-43		699-97-43	
	Depth	---		---		---		---		---		---	
	Type	WATER		WATER		WATER		WATER		WATER		WATER	
	Comments									EQUIPMENT BLANK		EQUIPMENT BLANK	
Parameter	Units	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q
ALUMINUM	UG/L	30.300	U	30.300	U	30.300	U	30.300	U	42.900	U	30.300	U
ANTIMONY	UG/L	32.800	U	32.800	U	32.800	U	32.800	U	32.800	U	32.800	U
BARIUM	UG/L	41.800	B	43.300	B	40.000	B	40.000	B	2.800	B	16.900	B
BERYLLIUM	UG/L	0.840	U	0.840	U	0.850	U	0.850	U	0.850	U	0.200	U
CALCIUM	UG/L	44600.000		45500.000		44300.000		44100.000		1520.000	B	16100.000	
CADMIUM	UG/L	3.800	U	3.800	U	3.800	U	3.800	U	3.800	U	3.800	U
CHROMIUM	UG/L	160.000		159.000		178.000		169.000		2.900	U	2.900	U
COBALT	UG/L	4.100	U	4.100	U	4.100	U	4.100	U	4.100	U	4.100	U
COPPER	UG/L	5.000	U	5.000	U	5.000	U	5.000	U	12.500	B	7.000	B
IRON	UG/L	15.600	BJ	8.100	U	92.300	BJ	9.600	BJ	19.400	BJ	18.200	BJ
MAGNESIUM	UG/L	12300.000		12500.000		10000.000		9950.000		288.000	B	3620.000	B
MANGANESE	UG/L	0.800	UJ	0.800	UJ	1.600	BJ	0.800	UJ	0.810	BJ	0.800	UJ
NICKEL	UG/L	15.200	U	15.200	U	15.200	U	15.200	U	15.200	U	15.200	U
POTASSIUM	UG/L	5100.000		5210.000		4370.000	B	4310.000	B	2660.000	U	2660.000	U
SILVER	UG/L	5.300	U	5.300	U	5.300	U	5.300	U	5.300	U	5.300	U
SODIUM	UG/L	20800.000		21200.000		22100.000		22100.000		553.000	B	1850.000	
VANADIUM	UG/L	11.300	U	11.300	U	11.300	U	11.300	U	11.300	U	11.300	U
ZINC	UG/L	11.100	U	18.000	B	11.100	U	11.100	U	16.700	B	929.000	

The decimal places shown do not reflect the precision reported by the laboratory

1. PURPOSE

This procedure defines the system to be used for the calibration, control, and maintenance of measuring and test equipment and in-house calibration standards.

2. APPLICABILITY

This procedure is applicable to all measuring and test equipment used in geotechnical and chemistry laboratory analyses and field investigations that is owned by Golder Associates Inc. (Golder) or, at the direction of the Office Manager, is leased on a long-term basis. Use of personal equipment is prohibited unless it is calibrated and maintained in compliance with this procedure. This procedure does not apply to rented equipment.[1]

3. DEFINITIONS

3.1 Calibration

Calibration is defined as the periodic comparison of an instrument or measurement device to a standard of known and greater accuracy, in order to assure the continuity and accuracy of measurements or data. If no standards meeting the requirements of Section 3.2 exist, then the basis or justification of calibration method must be documented in individual equipment files.

3.2 Calibration Standard

A calibration standard is a device or reference used as a means of comparison for determining quantitatively the accuracy, precision, and repeatability of instruments or measurement devices. Calibration standards must have a traceable, known relationship to nationally recognized standards such as those maintained by the National Institute of Standards and Technology (NIST) or various US Environmental Protection Agency (EPA) standards.

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[1]Note: Rented equipment shall be supplied with calibration certifications demonstrating currency of calibration for the time period applicable to its use on Golder projects. Such certifications shall be traceable to the serial number of the leased equipment, and the equipment shall be labeled to indicate the next calibration due date.

4. RESPONSIBILITIES

4.1 Laboratory Manager/Equipment Manager

Each Laboratory Manager and/or Equipment Manager is responsible for the implementation of the calibration and maintenance program for all laboratory and field equipment owned by Golder, or, at the direction of the Office Manager, managed by Golder under long-term lease. Detailed responsibilities for implementation include:

- Establishment of an identification system for all laboratory and field equipment meeting the applicability requirements of Section 2; unique serial numbers shall be assigned to each piece of equipment in inventory;
- Assurance of the acceptable calibration status for all equipment, by use of a locator/recall system and, for stored equipment, review of calibration status labels prior to releasing for project work;
- Performance or direction of calibration and maintenance activities for all Golder-controlled instruments and equipment;
- Maintenance and development of a master equipment file, which contains, as applicable for the type of equipment, equipment calibration and maintenance instructions, established calibration intervals, definition of special shipping and handling requirements, and calibration documentation;
- Maintenance of suitable storage facilities and instructions for use and care of laboratory standards, separate from other tools and equipment in the calibrated inventory; and
- Review of all condition-found reports for equipment found to be out of calibration, and for preparation of technical memoranda evaluating the potential effect on measurements made with such instruments over the previous calibration interval.

Activities performed in support of these responsibilities may be delegated to qualified personnel.

4.2 Field or Laboratory Personnel

Equipment users are responsible for verifying acceptable calibration status of all equipment or instrumentation used during a test or analysis, and for returning such equipment to the applicable Laboratory Manager or Equipment Manager, or (for rented equipment) owner, when recalibration or maintenance is required.

4.3 Project Manager

Project Managers are responsible for assuring that the equipment or instrumentation procured for or selected for field or laboratory use on a project (or to implement specific Golder technical procedures) is of sufficient range, accuracy, tolerance, and construction to provide meaningful data or measurements. In addition, the Project Manager is responsible for assuring that all equipment or instrumentation procured for a particular project (or to implement specific Golder technical procedures) is routed through the applicable Laboratory Manager or Equipment Manager for assignment of equipment control numbers, entry of information into individual equipment files, establishment of calibration intervals, and entry into the applicable locator/recall system; and for notifying the Laboratory Manager/Equipment Manager when client calibration needs exceed existing standards and new requirements must be incorporated into the equipment file.

4.4 QA Manager

The QA Manager is responsible for initiating Corrective Action Requests (CARs; see QP-14.1, "Corrective Action") as required to address significantly out-of-tolerance equipment; and, for scheduling periodic internal audits or surveillances to monitor the effectiveness of the calibration program in compliance with QP-10.1, "Surveillance Inspection" or QP-17.1, "Quality Audits."

5. DISCUSSION

Calibration and maintenance of measuring and test equipment is required so that the accuracy and precision of data collected (and, potentially, the calculations based on the data) are known. Calibration should not be construed as the instrument adjustments or accuracy checks commonly performed during or as part of test operations, but rather consists of those systematic, periodic evaluations of instrumentation or equipment that verify performance within specified levels of accuracy, precision, and repeatability. Calibration shall be performed in a clean environment, giving due consideration for dust, relative humidity, temperature, and vibration, as necessary for the equipment being calibrated. Calibration records shall be retained in each laboratory or field equipment storage area. Copies of records specific to certain tests shall be forwarded to project QA records when requested.

6. PROCEDURE

6.1 Equipment Designation and Tagging

The responsible Laboratory Manager or Equipment Manager shall assign unique numerical designators to all measuring and test equipment within their assigned inventories. Designator assignment should be logical based on the type or expected use of the instrument or equipment. If system components can be used in another application, the individual components should be labeled with a unique number. Calibrated equipment shall have a readily visible calibration tag (see Figure 6-1) affixed indicating calibration acceptance, date of last calibration, recall date, initials of the person performing the calibration, and the equipment number. If calibration is performed by an external service, functionally equivalent labels provided by the supplier may be used in lieu of Golder labels. Labels for equipment calibrated with each use shall be marked to indicate "user" or "Golder" in the "calibrated by" blank, and "each use" in the calibration date blank. This requirement does not apply to equipment normally subjected to adjustments or operational checks before use; such adjustment is not considered calibration as defined in Section 3.1. Equipment with expired calibration shall be tagged with a red tag indicating "Out of Service" (see Figure 6-1).

6.2 Calibration Interval

The required calibration interval shall be assigned by the responsible Laboratory Manager or Equipment Manager. In no case shall the calibration interval exceed the maintenance interval. The calibration interval shall be based, as appropriate, on manufacturer's recommendations, the level of projected use, the probable usage environment, and usage history.

6.3 Recall Date

The recall date shall present the date by which the equipment must be withdrawn from service for calibration and/or routine maintenance.

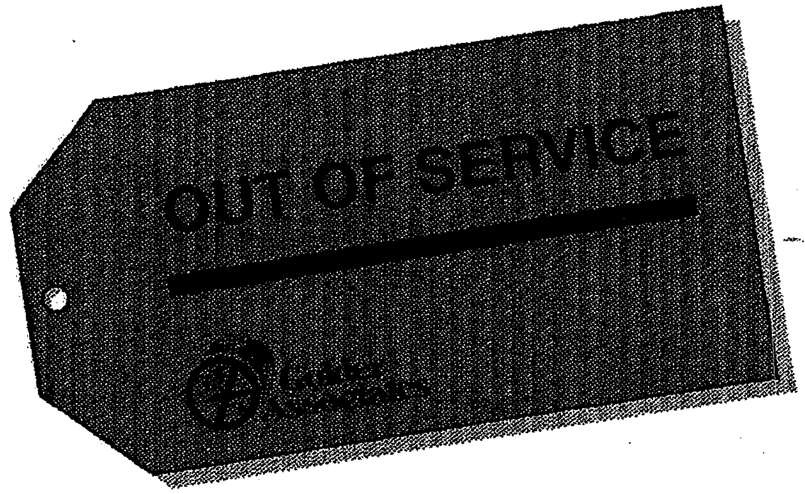
6.4 Equipment File

Each Laboratory Manager or Equipment Manager shall develop and maintain a comprehensive equipment file which contains, by equipment number, specific calibration instructions, original calibration certifications (as applicable), calibration intervals, maintenance instructions, storage requirements, special handling requirements, calibration history (as applicable, including condition-found reports for each calibration), and, if appropriate, reference to the project that it was originally procured against. Any limitations on use shall be specifically defined; laboratory calibration standards shall not be used as measuring or test devices beyond the scope of their calibration functions. Whenever possible, the Laboratory Manager or Equipment Manager shall provide a range of tolerance for the equipment, beyond routine calibration limits but beyond which the technical results obtained with the equipment may be questionable and should therefor prompt a condition-found investigation as described in Section 6.6. Equipment calibration and maintenance requirements shall be summarized on the form provided as Figure 6-2. Final records shall be produced in ink; supporting worksheets and graphs may be prepared in pencil. Use of whiteout or correction tape is prohibited.

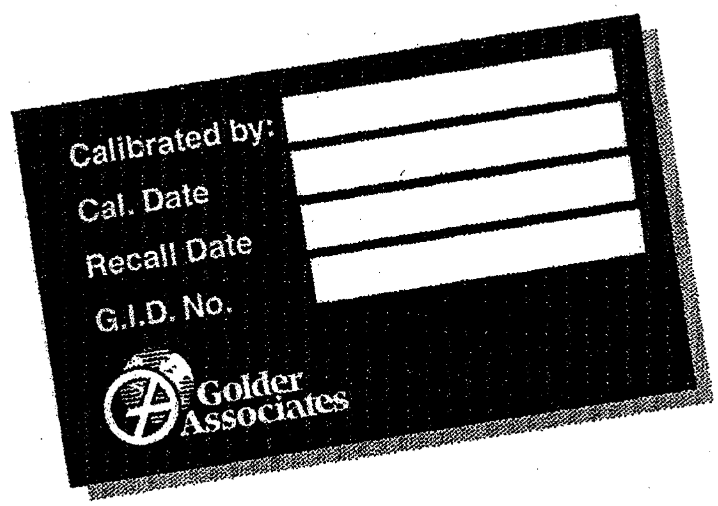
6.5 Calibration Sources

Calibration may be performed internally under the direction of the responsible Laboratory Manager or Equipment Manager, or by qualified external sources. Calibration methods shall be as defined for the specific equipment item in the applicable Equipment File. Regardless of whether the calibration is performed internally or by an external source, all

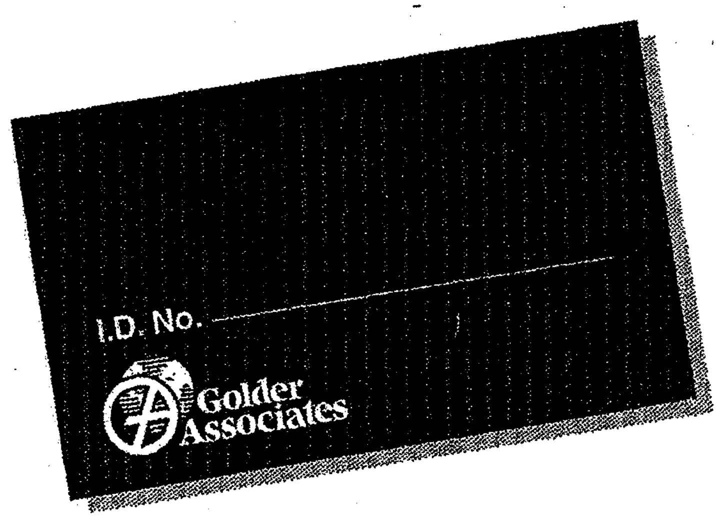
Out of Service Tag



Calibration Label



Identification Label



Note: Tag and labels not to scale

FIGURE **6-1**

MEASURING AND TEST EQUIPMENT LABELS

QP-11.1

PROJECT NO. IP3 0020.000 DRAWING NO. 48620 DATE 1/28/94 DRAWN BY CB

EQUIPMENT CALIBRATION/ MAINTENANCE REQUIREMENTS

Golder Associates

Equipment Number: ____________________

Equipment Name/Model Number: ____________________

Calibration Interval: ____________________

Calibration Instructions: ____________________

Maintenance Interval: ____________________

Maintenance Instructions: ____________________

Condition-found Investigation Required Beyond (provide range): ____________________

Special Storage/Handling Requirements: ____________________

Golder Associates Inc.

FIGURE **6-2**

EQUIPMENT CALIBRATION/ MAINTENANCE REQUIREMENTS FORM

QP 11.1

PROJECT NO. IP3 0020.000 DRAWING NO. 53110 DATE 6/23/94 DRAWN BY EA

Golder Associates

reference standards shall be traceable to nationally recognized standards. If no standards exist, written justification of the calibration method must be a permanent part of the equipment file. Procurement documents for calibration and maintenance services shall require the source to perform the calibration and maintenance to established procedures with traceability to nationally recognized standards, or to provide appropriate method descriptions and justification if no standards exist. The procurement document shall also require the source to provide a condition-found report and certificates of calibration (and records of maintenance, if a regular maintenance cycle is required) with the equipment when it is returned to Golder. This documentation shall be reviewed by the responsible Laboratory Manager or Equipment Manager for compliance with procurement requirements, prior to accepting the equipment into inventory and subsequent release for project use.

6.6 Condition-Found Report

Records of internal or subcontracted calibrations shall document the as-found calibration status of all equipment. The responsible Laboratory Manager or Equipment Manager shall review the condition-found information so provided to determine if out-of-tolerance conditions existed beyond the permissable range defined by the associated Equipment Calibration/Maintenance Requirements form. If excessive out-of-tolerance conditions are noted, the responsible Laboratory Manager or Equipment Manager shall determine the potential effect of the condition on measurements performed during the previous calibration interval and shall document the results of such determinations by a memo to the equipment file and QA Manager. If significant out-of-tolerance conditions have been identified, the QA Manager shall initiate a CAR, which shall be documented and resolved in compliance with QP 14.1, "Correction Action." See Section 6.10 below.

6.7 Equipment Tracking and Recall System

The Laboratory Manager/Equipment Manager is responsible for the maintenance of a system for controlling the issue of equipment, maintaining visibility of equipment location and calibration due dates, and issue of recall notices for recalibration and maintenance. The system may be maintained manually, or may be computerized, but in either case shall initiate recall activity well in advance of the calibration expiration dates in order for project managers to plan for equipment downtime.

6.8 Storage and Special Handling

Storage requirements shall be as specified by the manufacturer or in accordance with accepted industry practice. Equipment and reference calibration standards shall be used only for their intended purposes. They shall be adequately protected from moisture, dust, atmospheric contamination, and physical damage. Calibrated instruments being shipped or transported to field operations shall be securely packaged to prevent damage or loss of calibration due to shock, vibration, extremes of temperature, or moisture, and shall contain all required user manuals, in protective plastic coverings. Damaged equipment shall be tagged with a red "Out of Service" tag (see Figure 6-1). If the date of equipment damage cannot be determined, the equipment shall be considered out of calibration, and addressed as a nonconformance (see Section 6.10).

6.9 Surveillance Inspections or Audits

At the direction of the QA Manager, surveillance inspections or audits shall be conducted periodically to verify compliance with this procedure, per the requirements of procedures QP-10.1, "Surveillance Inspection" and QP-17.1, "Quality Audits." Frequency shall be as defined by governing QA program plans.

6.10 Calibration-Related Nonconformances and Audit Findings

When use of equipment with expired calibration, no calibration, or damage is observed in a surveillance inspection or audit, the situation shall be documented as a nonconformance, finding, or observation, and resolved in compliance with QP-14.1, "Corrective Action." Resolution shall include a technical evaluation by the responsible Laboratory Manager or Equipment Manager of the validity of test results obtained through the use of the equipment since its last calibration date.

7. REFERENCES

- Golder Associates Quality Procedure QP-14.1, "Corrective Action"
- Golder Associates Quality Procedure QP-17.1, "Quality Audits"
- Golder Associates Quality Procedure QP-10.1, "Surveillance Inspection"

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Record of Revision

QP-14.1

Revision Level -5-

Section	Description of Revision
4.1 4.3 4.4 5. 6.1.4	Added assessment of effectiveness.
3.2	Clarified definition of "nonconformance".
Figure 4-1	Added reference to follow-up audit on surveillance and subsequent CARs.
Figure 6-1	Added assessment of effectiveness.

Ref: ABS QE CAR 30798C-04

s:\IP3-0020\QP14-1.RV5

1. PURPOSE

This procedure defines the process for selection and implementation of the actions necessary to correct immediate nonconforming conditions and to reduce or preclude the recurrence of the identified condition, and to identify and eliminate potential causes of nonconforming conditions.

2. APPLICABILITY

This procedure applies to nonconforming conditions and potential causes of nonconforming conditions which have been identified through Golder Associates Inc. (Golder) inspection, auditing, management review activities, client feedback, or by project staff during the routine performance of work.

3. DEFINITIONS

3.1 Corrective Action

Corrective action consists of the measures taken to correct the immediate adverse conditions and to reduce or preclude the recurrence of an adverse condition. Examples might include: revising procedures for clarity or to resolve conflicting interpretations or instructions; conducting specific training exercises relative to a nonconformance; evaluating and selecting alternate suppliers or subcontractors.

3.2 Nonconformance

A nonconformance is a deficiency in characteristic, documentation, or procedure which renders the quality of material, equipment, services, or activities unacceptable or indeterminate. If the nature of the condition is such that if it is not corrected it may result in a permanent and significant impact on the quality of the item, test, or report, it must be brought to the attention of the Project Manager and QA Manager for resolution and concurrence on the scope of required corrective action. Examples of nonconformances might include the following: incomplete or inadequate technical reviews; testing not in accordance with procedures; sample traceability missing or deficient; sample collection not as prescribed by procedures; use of uncalibrated instrumentation for testing, measurement, or analysis.

When the deficiency is of a minor nature, does not effect a permanent or significant change in quality if it is not corrected, and/or can be brought into conformance with immediate corrective action, it is not categorized as a nonconformance. Such situations might include: modifications to a deliverable required as a result of the technical review process, commercial grade items shipped in error returned immediately to the supplier, technical reviews signed but undated; use of pencil instead of ink; typographical errors in reports.

3.3 Preventive Action

Preventive actions are the actions taken to eliminate the causes of a potential nonconformity in order to prevent occurrence.

4. RESPONSIBILITIES

4.1 QA Manager

The Quality Assurance (QA) Manager is responsible for documenting nonconforming conditions resulting from inspection or nonconformances identified by project staff on Corrective Action Reports (CARs, see Figure 4-1), for participating in the determination of root causes and the selection of appropriate corrective action, for verifying satisfactory implementation of the corrective action, and for assessing the effectiveness of the action. The QA Manager is also responsible for tracking CARs from initiation to closure.

The QA Manager is responsible for documenting Preventive Action activities, for participating in determination of appropriate actions, for verifying completion of the preventive action, and for assessing the effectiveness of the action.

4.2 Project Manager

The Project Manager is responsible for participating in the determination of root causes and the selection of appropriate corrective action, and for reporting potential causes of nonconforming conditions to the Office Manager or QA Manager.

4.3 Lead Auditors

Lead Auditors are responsible for documenting nonconforming conditions and participating in root cause evaluation and corrective action selection for findings and observations resulting from internal audits performed in compliance with QP-17.1, "Quality Audits," for verifying satisfactory completion of corrective actions, and for assessing the effectiveness of the action. Lead Auditors are also responsible for reporting potential causes of nonconforming conditions identified during audit activities to the Office Manager or QA Manager.

4.4 Management Reviewer

The Management Reviewer is responsible for documenting nonconforming conditions and for participating in root cause evaluation and corrective action selection for nonconformances resulting from management reviews performed in accordance with applicable quality management plans, for verifying completion of those corrective actions, and for assessing the effectiveness of the action.

CORRECTIVE ACTION REQUEST

Golder Associates

Page 1 of ___

CAR NO.:

Type: ___ Nonconformance
___ Finding (No.________________)
___ Observation (No:________________)

Issue Date: ____________
Reported By: ____________
Initiating Document: ____________
Project (if applicable): ____________

Meeting to determine root cause, corrective action, action assignment, and completion date:
Date: ____________
Attendees: ____________
Project Manager: ____________
QA Manager: ____________

Action Assigned To: ____________ Completion Date: ____________
RETURN TO QA MANAGER UPON COMPLETION OF CORRECTIVE ACTION WITH SUPPORTING DOCUMENTATION AS APPROPRIATE

Requirement: ____________

Description of Discrepancy: ____________

Root Cause: ____________

QA Manager/Date | Project Manager/Date | Other/Date

Corrective Action: ____________

QA Manager/Date | Project Manager/Date | Other/Date

Closure:
Completion Verified: ____________
Signature/Title/Date

Effectiveness Assessed: ____________
Audit or Surveillance Number

Subsequent CAR Number (if applicable): ____________

Golder Associates Inc.

FIGURE **4-1**
CORRECTIVE ACTION REQUEST
QP-14.1

PROJECT NO. IP3 0020.000 DRAWING NO. 48457 DATE 5/20/97 DRAWN BY CB

The Management Reviewer is also responsible for reporting potential causes of nonconforming conditions identified during management review activities to the Office Manager or QA Manager.

4.5 All Personnel

All personnel are responsible for notifying their Project Manager, the Office Manager, and/or QA representative when actual or potential nonconforming conditions are suspected.

4.6 Office Manager

The Office Manager is responsible for participating in determination of appropriate preventive actions.

5. DISCUSSION

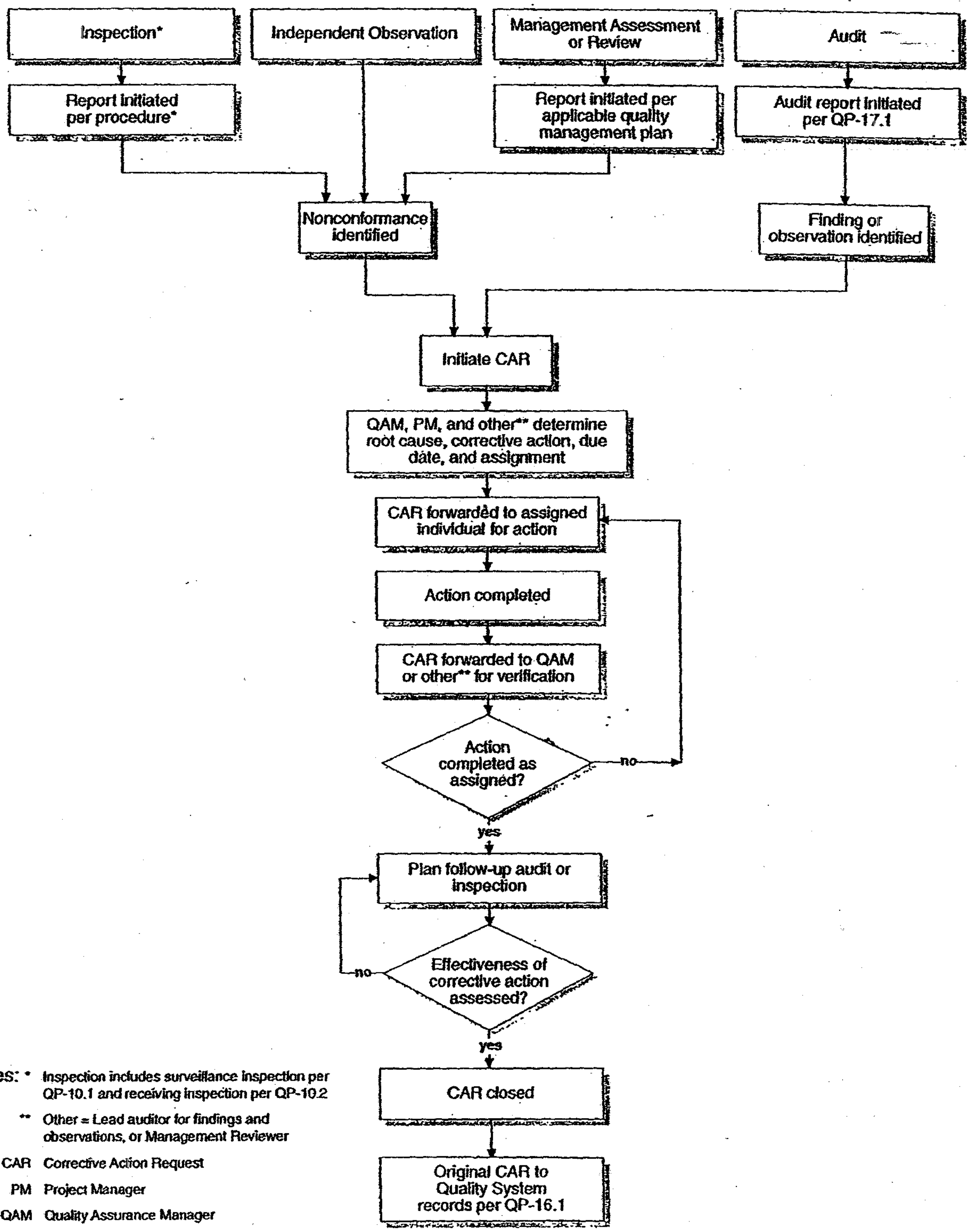
The corrective action process shall be initiated when nonconforming conditions have been identified through inspection, auditing, or management review activities, or by client feedback or Golder personnel during the routine performance of work. Nonconforming conditions and subsequent corrective actions shall be documented on CARs. The root cause, corrective action to be implemented, and the scheduled completion date shall be cooperatively determined by the QA Manager, Project Manager, and, if applicable, the Lead Auditor or Management Reviewer. Other personnel may be included in the corrective action process as deemed appropriate by the QA Manager or Project Manager. The QA Manager, Lead Auditor, or Management Reviewer (as applicable) shall verify completion of the required actions, and assess their effectiveness. Closed CARs shall be maintained in the Quality System records in accordance with QP-16.1, "Quality Assurance Records Management."

The preventive action process shall be initiated when potential causes of nonconforming conditions are identified through inspection, auditing, or management review activities, or by client feedback or by Golder personnel during the routine performance of work. Appropriate preventive actions shall be determined by the Office Manager and QA Manager. Preventive actions shall be documented, completion shall be verified, and the effectiveness of the action shall be assessed. Records of preventive actions shall be maintained in the Quality System records.

6. PROCEDURE

6.1 Corrective Action Process

The corrective action process is described graphically in Figure 6-1; specific steps in the process are described in the following sections.



Notes: * Inspection includes surveillance inspection per QP-10.1 and receiving inspection per QP-10.2

** Other = Lead auditor for findings and observations, or Management Reviewer

CAR Corrective Action Request

PM Project Manager

QAM Quality Assurance Manager

QP-10.1 "Surveillance Inspection"

QP-10.2 "Receiving Inspection"

QP-16.1 "Quality Assurance Records Management"

QP-17.1 "Quality Audits"

FIGURE **6-1**
CORRECTIVE ACTION PROCESS
QP-14.1

PROJECT NO. IP3 0020.000 DRAWING NO. 48541 DATE 5/20/97 DRAWN BY CB

Golder Associates

6.1.1 Identification of Conditions Requiring Corrective Action

Discrepant conditions may be identified through inspection (see procedures QP-10.1, "Surveillance Inspection" and QP-10.2, "Receiving Inspection"), auditing (see QP-17.1, "Quality Audits"), management review activities, or by personnel during the routine performance of work. Each discrepant condition that is categorized as a nonconformance, finding, or observation, as specified in the governing procedures noted above, shall be documented on a Corrective Action Request (CAR) by the QA Manager, Lead Auditor, or Management Reviewer (as applicable) for resolution. CARs shall be uniquely numbered and logged for tracking purposes. The log shall include at a minimum:

- CAR number
- Initiating document, if applicable (audit report, inspection report, or management review report)
- Issue Date
- Assigned recipient
- Closure date

The QA Manager shall monitor the progress of CARs from initiation through closure.

6.1.2 Root Cause Analysis

The QA Manager, cooperatively with the Lead Auditor or Management Reviewer, (as applicable) and Project Manager shall evaluate each CAR to determine the root cause of the condition. The root cause is the fundamental cause under management control that, when corrected, will prevent recurrence of the adverse condition. The root cause shall be recorded on the CAR, and approved by the QA Manager, together with the Management Reviewer, or Lead Auditor (as applicable), and the Project Manager.

6.1.3 Corrective Action Selection

After the root cause of the condition has been determined, the QA Manager, cooperatively with the Lead Auditor or Management Reviewer (as applicable) and the Project Manager shall jointly determine the appropriate corrective action and action completion date. Corrective action measures shall be selected to correct the immediate condition and, as necessary, to prevent or reduce the likelihood of future occurrences of the condition. Selected actions shall be appropriate in relation to the seriousness of the condition, and shall be realistic in terms of the resources required for proper implementation. Where agreed as appropriate, such actions may include suspending or placing additional controls on related activities until the required actions are complete. Previous occurrences and/or trends of similar conditions shall be considered in the determination of appropriate corrective actions. The effectiveness of previous corrective actions for similar conditions shall be investigated and shall be factored into the selection of corrective actions of a level and type appropriate for the current condition.

The selected corrective actions shall be recorded on the CAR and approved by the participants.

6.1.4 Corrective Action Implementation and Verification

Corrective action activities shall be assigned to the appropriate individual by the Project Manager, or the CAR signatory who is responsible for the corrective action activities. The CAR shall be forwarded to the assigned individual for action.

When corrective action has been completed, the assigned individual shall forward the CAR, along with supporting documentation as appropriate, to the QA Manager, Management Reviewer, or Lead Auditor (as applicable) who will verify completion of the activities. After the activities have been verified as complete and satisfactory, the effectiveness of the actions shall be assessed via auditing or surveillance inspection activities. The applicable audit or surveillance number, along with any subsequent, related CAR numbers, shall be noted on the existing CAR. The original CAR and supporting documentation shall be forwarded to the QA Manager and shall be maintained in the Quality System records.

When procedure or plan revisions are the result of corrective actions, they shall be identified as such in the record of revisions for the updated document.

6.2 Preventive Action Process

Potential causes of nonconforming conditions may be identified through various sources of information, including but not limited to the following:

- Audit results
- Management review results
- Client feedback
- Surveillance inspection results
- Staff observation and feedback.

Potential causes of nonconforming conditions shall be reported to the QA Manager or the Office Manager who shall jointly determine if preventive actions are appropriate. If so, preventive actions necessary to prevent occurrence of the potential nonconformance shall be jointly determined by the QA Manager and Office Manager, based on input elicited from appropriate personnel. Selected preventive actions shall be appropriate in relation to the seriousness of the potential nonconformance and shall be realistic in terms of the resources required for proper implementation. An individual(s) shall be assigned responsibility for completion of the selected actions.

The QA Manager shall document the condition, the potential nonconformance, the required preventive actions, and the individual assigned responsibility for completing the actions. Upon completion, the QA Manager shall verify and document that the actions were completed as required.

Records of preventive actions shall be maintained in the Quality System Records in accordance with QP-16.1, "Quality Records Management." When procedure or plan revisions are the result of preventive actions, they shall be identified as such in the record of revisions for the updated document.

The effectiveness of preventive actions shall be assessed via auditing or surveillance inspection activities.

7. REFERENCES

- Golder Associates Procedure QP-16.1, "Quality Assurance Records Management"
- Golder Associates Procedure QP-17.1, "Quality Audits"
- Golder Associates Procedure QP-10.1, "Surveillance Inspections"
- Golder Associates Procedure QP-10.2, "Receiving Inspection"

Record of Revisions
QP-16.1
Revision Level -4-

Section	Description of Revision
3.2 3.4 4.7 5. 6.4	Added or updated to address electronic records for all sections noted

Reference ABS QE CAR 30798-B-03

1. PURPOSE

This procedure provides the methodology for the collection, storage, maintenance, retrieval and turnover of Golder Associates Inc. (Golder) Quality Assurance records.

2. APPLICABILITY

This procedure applies to the management of all completed documents that provide evidence of the quality of items or activities affecting quality on projects conducted by Golder personnel.

3. DEFINITIONS

3.1 Quality Assurance Records

Quality Assurance (QA) records are completed, legible documents which furnish objective evidence of the quality of items or services, activities affecting quality, or the completeness and quality of data.

3.1.1 Project QA Records

Project QA records are defined as QA records that are maintained for a specific project. Examples include contractual documents, incoming and outgoing correspondence, project deliverables, technical review documentation, field notes or logbooks, and Specific Work Instructions.

3.1.2 Quality System Records

Quality System records are defined as those QA records which may generally be drawn upon to support the quality program requirements of all projects or the system as a whole. Such records may include quality procedures, technical procedures, personnel training records, audit records, and other records for which QA staff are directly responsible. If a client requires certain types of Quality Systems records as part of project QA records, duplicate records will be provided.

3.1.3 Procurement Records

Procurement Records are those records maintained as evidence of specific procurement activities, such as purchase orders, invoices, receiving inspection documentation, and subcontracts. Such records may be in regard to a specific project or to general office activities.

3.2 Records Index

A records index is an actively updated list of the project QA records, Quality System records, Procurement records, or electronic records which defines the location of the records within the filing system.

3.3 QA Records Center

The QA Records Center is a locking, fire resistant room with controlled access in which project QA records are normally stored.

3.4 Electronic Records

Electronic records are electronic files stored in the computer system which are not represented in either hard copy or electronic form in another of the records systems listed above, but are depended upon for implementation of the quality program. Examples include the Archives Database which lists all records stored in the off-site archives facility and the Document Control Database which tracks controlled distribution of procedures and plans to individuals. Examples of files NOT INCLUDED in this records category are word processing and CAD files, for which a hard copy of the completed document or drawing is included in the Project QA Records.

4. RESPONSIBILITIES

4.1 Project Manager

The Project Manager is responsible for establishing the basic project structure by dividing project activity into individual tasks, and for providing guidance in the design of the project records index based on the resulting task structure.

4.2 Project Secretary

The Project Secretary is responsible for designing the Project Records Index in cooperation with the Records Manager and with guidance from the Project Manager.

4.3 Project Personnel

All project personnel are responsible for submitting completed documents in a timely manner for validation and forwarding to the project QA records.

4.4 QA Manager (or designee)

The QA Manager is responsible for the maintenance of the Quality System records and their associated index.

4.5 Records Manager

The Records Manager is responsible for design of the Project Records Index in cooperation with the Project Secretary, based on guidance from the Project Manager; production and maintenance of the Project Records Index; and for validation, storage, and control of project QA records. Records management activities may be delegated to the records staff.

4.6 Branch Accounting Manager

The Branch Accounting Manager is responsible for maintenance of the Procurement records and their associated index.

4.7 Information Systems Manager

The Information Systems Manager is responsible for the backup of electronic records and for storage of the backup files.

5. DISCUSSION

This procedure addresses Quality Assurance records, which fall into several categories: QA records maintained for a specific project, Quality System records which may be drawn upon to support all project QA programs or the system as a whole, Procurement records and electronic records. A client may require that certain types of Quality System records (e.g., personnel training records, quality plans, or procedures) or Procurement records be included in the project QA records. In such cases, copies will be routed to the project files and handled as original project QA records. Project QA records are reviewed by the Project Secretary and validated by the Records Manager prior to filing. Original project QA records are normally stored under the control of the Records Manager in the QA Records Center. Quality System records are stored in fire-resistant, locking cabinets under the control of the QA Manager. Procurement records are stored in fire-resistant locking cabinets under the control of the Branch Accounting Manager. Access to records is further controlled by a formal checkout system. Electronic records are located in various protected directories as noted on the Electronic Records Index and are backed up regularly.

6. PROCEDURE

6.1 Project QA Records

6.1.1 Project Records Index

At the beginning of each project, a Project Records Index shall be designed which provides the basic structure of the project filing system. The first Index produced identifies the types of records anticipated for the project and assigns a location in the filing system for each type. As the project progresses, the Index shall be updated as appropriate to include increasingly specific information. The Index shall be designed in a cooperative effort by the Project

Secretary and the Records Manager. The Project Manager shall provide guidance in the design of the Index based on the project structure and the division of the project activities into job tasks.

As a minimum, the Project Records Index shall include:

- The Golder job number
- The Project Manager and Records Manager
- The client contract number
- The project title
- A numerical listing of the files
- The title of the file associated with each number. The title shall be specific enough to allow easy retrieval and filing of records.

The Records Manager shall produce the Index and update it on a regular basis.

6.1.2 Collection and Validation

Project personnel who generate documents in support of a project shall submit the completed documents to the Project Secretary.

The Project Secretary shall review each document to ensure that completeness is indicated at the level required by the appropriate quality procedure (e.g., all required signatures are present), legible, identified with the project number, and contains sufficient information to permit identification between the document and the activity to which it applies. If problems are identified, the document may be returned to the preparer for resolution. After ensuring completeness, the Project Secretary shall forward project records to the Records Manager on at least a weekly basis. The Records Manager shall assign a file number to the document based on the Project Records Index and shall validate each document by applying a dated records stamp, or by initialing and dating the document. Validated documents shall be filed in the appropriate location in the project QA records. Completed documents awaiting validation and/or entry into the project QA records shall be temporarily stored during non-working hours in a locking file cabinet, or locking, access-controlled file room.

6.1.3 Storage Requirements

Project QA records are normally stored in the QA Records Center by the Records Manager. However, when acceptable to the QA Manager and the Project Manager, records may be stored in another location which has access controls commensurate with those described in Section 6.1.4 of this procedure. In either case, records shall be stored in a manner which effectively prevents deterioration or damage from natural disasters or environmental conditions. Records shall be stored in binders, folders, or envelopes in metal cabinets or on shelving in containers. Records files shall be organized separately by project and in accordance with the individual Project Records Index. Specially processed records such as photographs, negatives, and magnetic media shall not be stored in stacks and shall be protected from excessive light, electromagnetic fields, and excessive temperatures and humidity, as appropriate for the record type.

6.1.4 QA Records Center Access

Access to the QA Records Center shall be limited to those personnel who have a need for ongoing routine access. The Records Manager shall compile a list of personnel authorized for direct access to the QA Records Center. The list shall be posted outside the Records Center. Other personnel shall be escorted by an authorized individual, or may have access by permission of the Records Manager. The QA Records Center shall remain locked when unattended. The keys shall be held by the Records Manager.

6.1.5 Records Retrieval

Individuals may request that files or individual records be retrieved by the Records Manager for their use. Outcards shall be inserted to replace removed items.

6.1.6 Corrections and Revisions

Records shall be corrected by drawing a single line through the incorrect information and initialing and dating the new entry. Records requiring formal change control [e.g., plans, procedures, Specific Work Instructions (SWIs; see procedure QP-9.1 "Specific Work Instructions")] shall be revised in accordance with applicable procedures. Approval of the revision must be equivalent to the level and/or type of approval required for the original information, or as directed by SWI.

6.1.7 Retention Time

Project QA records for active projects shall be maintained in the project QA records files described in section 6.1.3. At the close of a project, as determined by the Project Manager, project QA records may be transferred to the Golder archives facility. Records shall be stored permanently unless directed otherwise by the client or Golder's General Counsel. Records transferred to the archives shall remain accessible, but shall no longer be subject to the other requirements of this procedure.

6.1.8 Records Turnover

Records shall be turned over to the client at their request. Records which have been turned over are the property of the client and maintenance of those records will no longer be considered the responsibility of Golder Associates.

Records to be turned over to the client shall be packaged securely for shipping. Each package of records shall contain an index of the records in that package and shall be clearly labeled as to client, project number, and total number of packages in the shipment. A set of indexes shall be sent to the client under separate cover. Additional requirements may be specified by the client.

6.2 Quality System Records

6.2.1 Quality System Records Index

The Quality System Records Index shall list and provide the location of the records in the Quality System records files. The QA Manager shall ensure that the index is updated as necessary to reflect changes.

6.2.2 Records Storage Requirements

Quality System records shall be stored in locking, fire-resistant file cabinets. The QA Manager shall maintain control of the keys. QA staff performing records filing functions shall verify the legibility of all documents placed in the file.

6.2.3 Records Access Control and Retrieval

Access to Quality System records shall be limited to personnel requiring ongoing routine access. A list of personnel authorized for direct access to the files shall be posted on each cabinet. Others may gain access by permission of the QA Manager. Individuals may request retrieval of files or individual records for their use from authorized personnel. Outcards shall be inserted in place of removed items.

6.2.4 Quality System Records Transfer

Quality System records meeting the following conditions shall remain in the Quality System records files, and shall be subject to the requirements of this procedure:

- records relative to the current and immediately previous year;
- records relative to the current and immediately previous revision of active documents; and
- records relative to current Golder employees.

At the discretion of the QA Manager, other Quality System records may be removed from the files and transferred to the Golder archives facility. Quality system records shall be stored permanently unless directed otherwise by General Counsel. Transferred records shall remain accessible, but shall no longer be subject to the other requirements of this procedure. Examples of Quality System records that may be transferred to the archives include obsolete plans and procedures, audit and surveillance inspection records from two or more years ago, and training records for terminated employees.

6.3 Procurement Records

6.3.1 Procurement Records Index

The Procurement Records Index shall list and provide the location of the records in the Procurement records files. The Branch Accounting Manager shall ensure that the index is updated as necessary to reflect changes.

6.3.2 Records Storage Requirements

Procurement records shall be stored in locking, fire-resistant file cabinets. The Branch Accounting Manager or designee shall maintain control of the keys. Cost Control staff performing filing functions shall verify the legibility of all documents placed in the file.

6.3.3 Records Access Control and Retrieval

Access to Procurement records shall be limited to personnel requiring ongoing routine access. A list of personnel authorized for direct access to the files shall be posted on each cabinet. Others may gain access by permission of the Branch Accounting Manager. Individuals may request retrieval of files or individual records for their use from authorized personnel. Outcards shall be inserted in place of removed items.

6.3.4 Procurement Records Transfer

Procurement records relative to the current and immediately previous year shall be maintained in the Procurement records files. At the discretion of the Branch Accounting Manager, other Procurement records may be transferred to the Golder archives facility. Records shall be stored permanently unless directed otherwise by General Counsel. Transferred records shall remain accessible, but shall no longer be subject to the other requirements of this procedure.

6.4 Electronic Records

6.4.1 Electronic Records Index

The Electronic Records Index shall list the electronic databases and logs that have been identified as formal records under this procedure. The Index shall include the location of each electronic file in the computer system and the individual responsible for file maintenance. The QA Manager shall ensure that the index is updated as necessary to reflect changes.

6.4.2 Electronic Records Access Control and Backup

Electronic records files shall be maintained in protected, access restricted locations in the computer system. Individuals allowed access to each file shall be determined by the individual responsible for file maintenance as listed on the Electronic Records Index.

The Information Systems Manager shall ensure that electronic records are backed up daily to avoid loss of data due to unforeseen circumstances. Backup files shall be stored on tape or other electronic media in an on-site fire-resistant location, or at an off-site facility.

6.4.3 Electronic Records Transfer

Electronic records that are not applicable to current project activity may be transferred to the Golder archives facility in electronic or hard copy format at any time determined appropriate by the individual responsible for file maintenance. Records shall be stored permanently unless directed otherwise by General Counsel. Transferred records shall remain accessible, but shall no longer be subject to the other requirements of this procedure.

7. REFERENCES

- Golder Associates Procedure QP-9.1, "Specific Work Instructions."